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WEEKLY 26 February 2022

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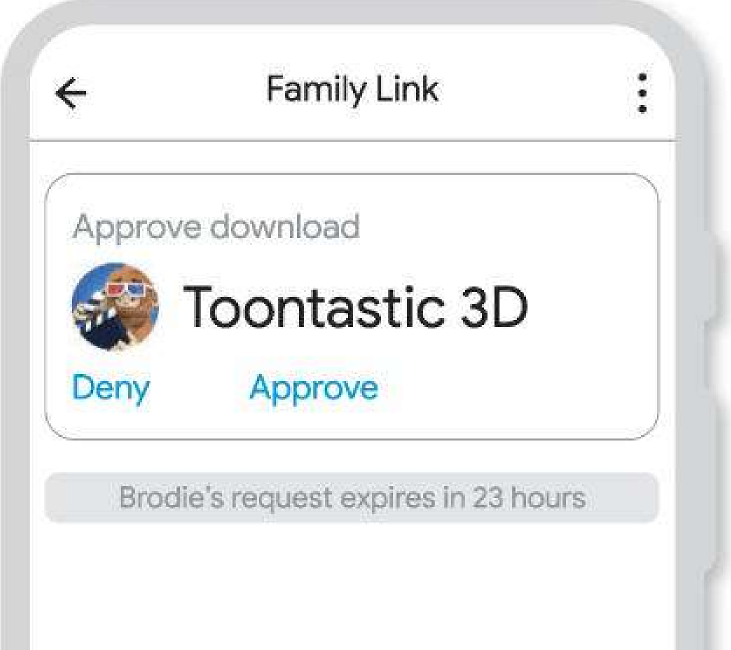

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New Scientist

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Weekly

A personalised medicine programme in Australia has saved the lives of more than 150 children with aggressive cancer. We hear a moving interview with one of their parents. Plus, we learn why lichens take much longer to evolve in response to climate change than you might think. Then, we get the latest on tests of "enhanced weathering", a technique to fight climate change by using ground-up rocks to draw carbon dioxide out of the atmosphere.

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MATTHEW NELSEN

Hot stuff Lichens evolve super slowly in response to climate change

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Mystery hominin How does *Homo erectus* relate to other humans?

Video

See the Endurance get crushed by ice

The British Film Institute has restored footage taken during one of Ernest Shackleton's expeditions to Antarctica, including the poignant moment when the mast of his ship, the Endurance, collapsed as the vessel was crushed by sea ice. Despite the sailors' perilous predicament, Shackleton insisted that the nitrate film was salvaged.

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Newsletter

Our Human Story

Get Michael Marshall's wonderful newsletter about human evolution delivered free to your inbox each month. In the latest edition, he looks at *Homo erectus*, simultaneously one of the best known and most baffling species of ancient human, and how it is related to the many other hominins.

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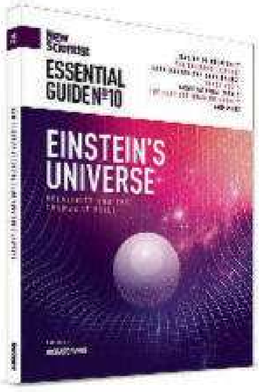
> **"*Homo erectus* existed for far longer than other human groups, but we don't know why"**



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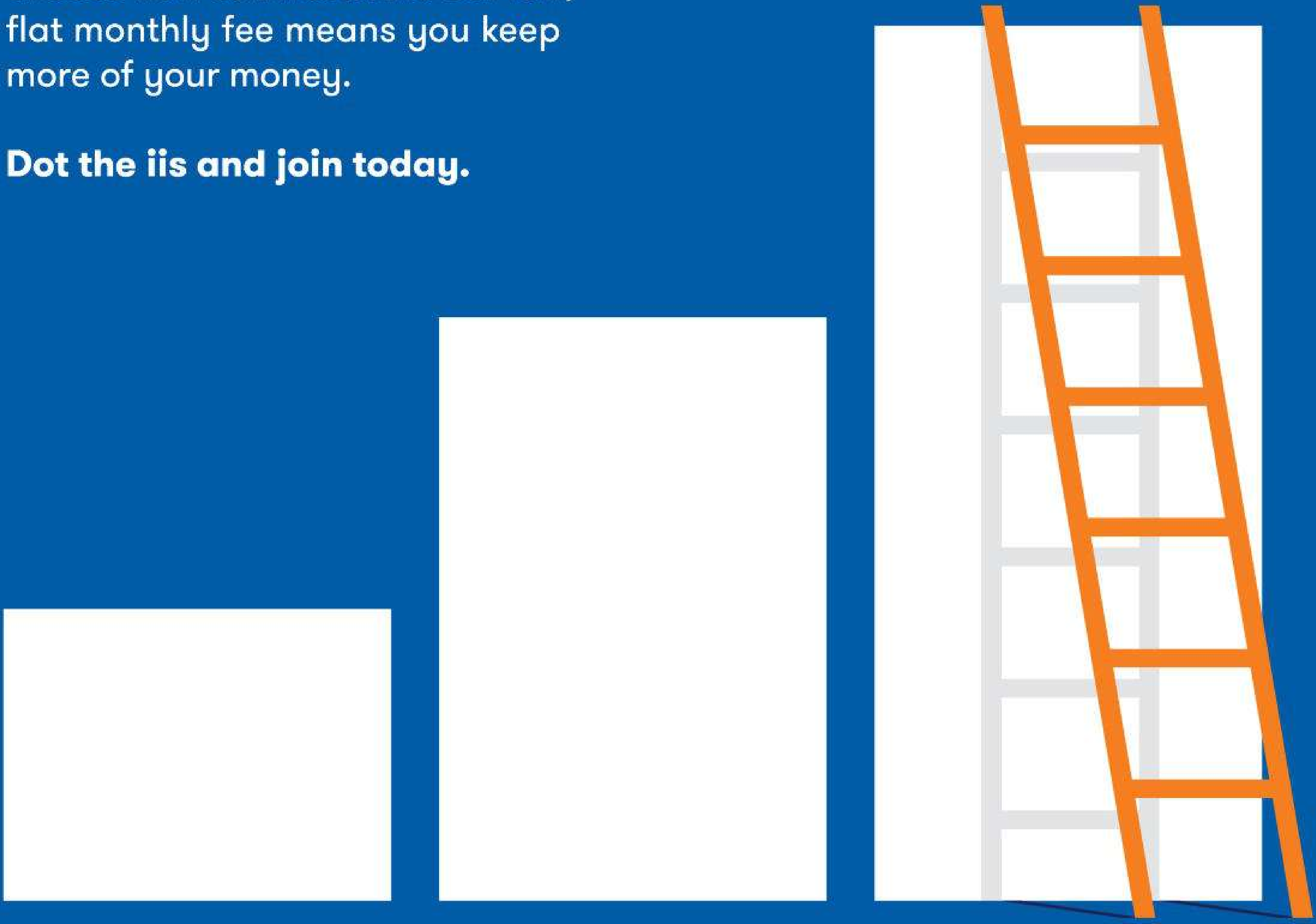

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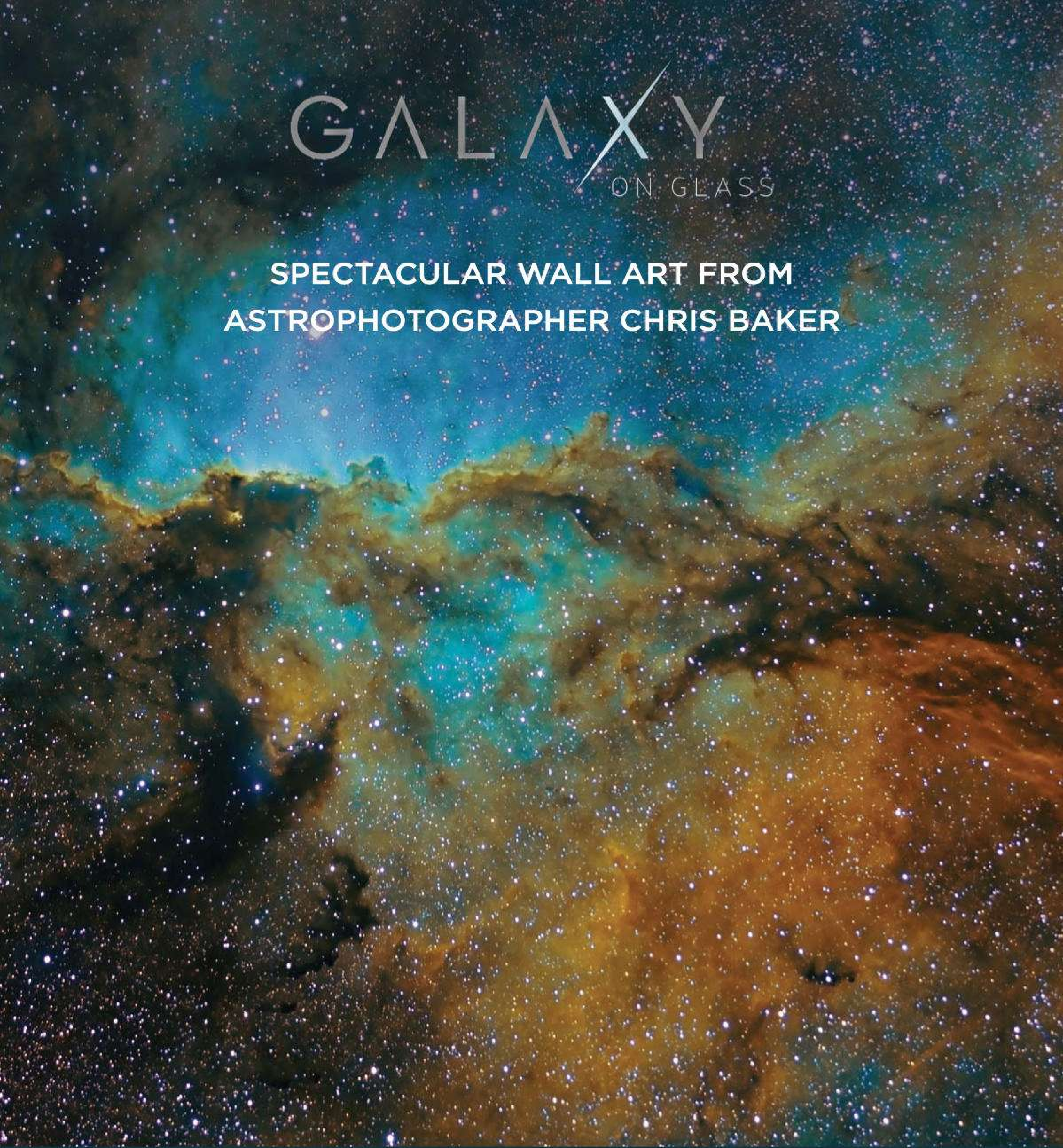

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The long covid dividend

Research into the syndrome could help others with similarly mysterious conditions

TOO many people are ill and can't be properly treated. They have "functional disorders" like myalgic encephalomyelitis (ME), aka chronic fatigue syndrome (CFS), that are life-altering and often disabling, but with unclear causes. Doctors struggle to find anything out of the ordinary in blood tests and other investigations. All they can do is try to relieve symptoms.

Now, tens of millions have developed a functional disorder at the same time: long covid. This can set in after infection with the SARS-CoV-2 virus and last for months or even years. Despite being initially dismissed by many doctors, people with long covid have campaigned for the illness to be recognised and studied.

Researchers have now identified possible underlying causes, and are devising and testing treatments, some of which may be in use this year (see page 38). This will have felt like a protracted wait for many of those with long covid, but is still an incredibly fast turnaround.

Other functional disorders need the same attention. In some cases, like ME/CFS, we have clues to what is going on, even if that hasn't yet led to treatments. Others, like fibromyalgia, a condition of widespread pain, are more mysterious. Diagnoses may be umbrella descriptions, hiding a range of physical goings-on that manifest as similar symptoms.

> "Just because a condition is unexplained, it doesn't mean it is unexplainable"

But "unexplained" doesn't mean "unexplainable". There is evidence many conditions can be traced back to infections with mild initial symptoms. Long covid isn't the only post-viral condition: for example, there is also a post-Ebola syndrome. Multiple sclerosis, a degenerative nervous system condition, seems almost exclusively to arise in people infected with the Epstein-Barr virus behind glandular fever, or "mono".

Functional disorders have been neglected for too long, despite their toll on people's well-being and society. The research momentum that has built up around long covid offers hope to the millions of people who have it, but also to millions with other functional disorders. Long covid looks like proof that these conditions, if they are pursued with enough determination and rigour, can be understood and properly treated. ▮

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AN IMPORTANT MESSAGE FROM PROFESSOR NICK LEMOINE CBE MD PHD FMEDSCI, CHAIR OF THE MEDICAL RESEARCH FOUNDATION

Gifts in Wills could be the key to protecting the future of human health

Our experience of COVID-19 shows how suddenly a global health challenge can appear. As someone interested in science, you will understand that while nobody can predict what we will face next, we can be certain that the future will bring many more threats to human health.

As Chair of the Medical Research Foundation – the charitable arm of the Medical Research Council – I have seen the incredible impact that individuals who remember the Foundation in their Wills can have on the future of our health and wellbeing here in the UK. These gifts fund research and researchers which can have far-reaching implications for human health.

With a gift in your Will you can play a key role in providing the science that will protect the health of future generations.

Right now, the Foundation is funding research to tackle antimicrobial resistance, and investing in researchers like Dr Myrsini Kaforou – who will make the fight against antimicrobial resistance her life's work.

Without support at the crucial early stages, researchers like Dr Kaforou can be forced to abandon their passion and leave science altogether, with an immeasurable loss to future human health. Gifts in Wills provide the long term funding and security that allows the Foundation to invest in projects like Dr Kaforou's and lay the foundations for quality research in years to come.

Your Will can fund the rational response to health challenges that medical science provides.

> **"As scientists, our duty is to secure the future of research for the generations that follow."**
>
> Professor Fiona Watt, Patron of the Medical Research Foundation and Director of the European Molecular Biology Organization.

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"The funding I received through the Medical Research Foundation will be transformative for my research." Dr Myrsini Kaforou

While we don't know what the future holds for human health in the UK, we do know that research, and the brilliant scientists driving that research forward, are the key to meeting those challenges for years to come.

But many of these scientists rely on the generosity and foresight of fellow members of the public – people like you, who understand the power of science and are willing to leave a gift to medical research in their Wills. At the Medical Research Foundation, over 90% of our voluntary income comes from individuals who choose to include a gift in their Will – they are crucial in the Foundation's ability to fund research that will enable the next generation of scientists to make real world discoveries in the future.

I firmly believe that a gift in your Will to the Medical Research Foundation is an excellent investment and will have a lasting impact on science and on the future of human health in the UK.

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Professor Nick Lemoine CBE MD PhD FMedSci
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Are poisonous toads killing Madagascar's native snakes? **p20**

Handy apes
Orangutans can't make stone tools, but can use them **p22**

CHRISTOPHER FURLONG/GETTY IMAGES

Public health messaging in Bolton, UK

Coronavirus

England ends covid-19 rules

Mandatory self-isolation ends in England as the country scraps its remaining coronavirus laws, reports **Adam Vaughan**

A "LIVING with covid" plan for England announced this week by UK prime minister Boris Johnson will see the country rely on guidance rather than legal rules backed with enforcement, almost two years after Johnson first ordered the nation into lockdown as the pandemic surged. It is about "moving from government restrictions to personal responsibility", he told the UK's parliament on Monday.

Self-isolation of people who test positive for the coronavirus became guidance rather than a legal requirement on 24 February, and routine contact tracing ceased. Testing will be scaled back, with PCR and lateral flow tests no longer free for all from April.

Whether the government is "following the science", as it claimed in the early stages of the pandemic, is an open question. At a press conference on 21 February, the chief scientific adviser to the UK government, Patrick Vallance, said: "There's no guarantee the next variant is as reduced severity as omicron. It could be the same, it could be more, could be less."

"It's not a science decision: none of the recent SAGE [Scientific Advisory Group for Emergencies] minutes suggest this is a good time to be doing this," says Christina Pagel at University College London. "We still have some of the highest infection rates we've had. I think it is the wrong time and sends the wrong message."

An end to free testing will impact the UK's covid-19 surveillance infrastructure. The UK's flagship monitoring scheme, the Office for National Statistics' covid-19 infection survey, will continue, with a breakdown by age and region to help track the disease. However, another random swabbing survey, REACT, run by Imperial College London, is expected to be axed at the end of March, *New Scientist* understands. Officially, no decision has been taken.

Whether the lifting of legal rules will drive a surge in England's covid-19 figures remains to be seen. The rolling seven-day average for daily cases stands at around 37,000 as of 13 February, the most recent figure, with around 1000 people admitted to hospital daily, while deaths have been relatively stable at more than 100 a day for most of February.

One glimpse into the future may come from Denmark, which lifted all legal covid-19 mitigations on 1 February. "I think it has proved to be the right decision," says Troels Lillebaek at Statens Serum Institute, Denmark. Cases have subsequently plateaued and are now falling.

Denmark has been accused by some people of seeing surging death rates after the relaxation, but Lillebaek says this stems from a misunderstanding about how Denmark counts deaths. Currently, about 60 per cent of people dying with covid-19 are dying due to the disease, and 40 per cent due to other causes. With the delta variant, covid-19 was causing around 80 per cent of deaths in people who had the disease.

Despite pressure on the healthcare system, it hasn't been overwhelmed, says Lillebaek. Most people are either discharged immediately or the next day after being assessed, he says.

"It's going as good as you could have hoped. We have been through the wave: in Copenhagen and Zealand it has already peaked," says Lone Simonsen at Roskilde University, Denmark. Extremely high booster vaccination rates in older age groups in Denmark have been key for making the relaxation possible, she says.

Nonetheless, she says that even with the protection offered by vaccinations, many people are still getting mildly sick. "It's not fun. [But] once you've had it, you can enjoy the silver lining of an excellent immunity," says Simonsen. ▮

Climate change

The day the floods came

Devastating floods in Germany last year have left deep scars that serve as a grim portent of Europe's climate future, reports **Adam Vaughan** from the Ahr valley

"I SAW a tree with people sitting in it, crying and screaming. I could hear them despite all the noise. But I couldn't help them. I didn't know what to do," says Melanie Schultz-Coerne, crying too as she recalls the traumatic night last year when Germany experienced its worst floods in six decades. She doesn't know what happened to the campers she saw, but 134 people in the country's Ahr valley died during the floods in mid-July, with hundreds more injured.

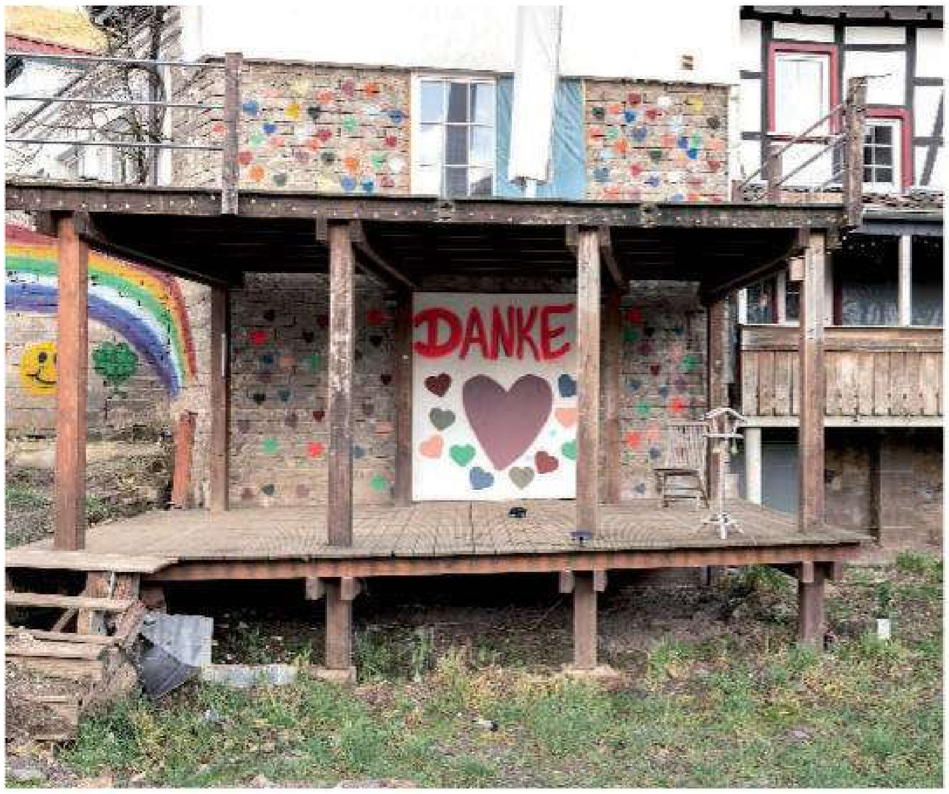
The increasing threat of such extreme weather events and their economic and human costs will come to the fore on 28 February when scientists release a major assessment of the impacts of climate change and, crucially, how we adapt to them (see "A road map for adaptation", right). The last version of this report, published by the Intergovernmental Panel on Climate Change (IPCC) in 2014, identified the harm wrought by floods as a key risk facing Europe.

One of the worst-hit areas last year was Ahr, named after the usually placid river snaking through it. Weeks after the flood hit Ahr, researchers linked it to climate change, finding the event to be a 1-in-500-year disaster.

Walking alongside the Ahr now, it is hard to imagine the river wreaking destruction on this affluent wine-growing region, which is popular with hikers and tourists. "We were a little paradise, with vineyards, a small river, bicycles. Then, one night, everything's gone," says Markus Kelter in Walporzheim. Standing in the gutted interior of the house where his family have lived since the 19th century, he is thankful that this time only the building was damaged. In 1804, children in his family died in a flood here.

The conditions for the 2021 flood were foreseen, says Frank Kreienkamp at Germany's National Meteorological Service. A low-pressure system sat in place for days, drawing warm, wet air from the Mediterranean that fell as rain over a wide area of north-west Europe. The extent and duration of the rain was striking, leaving the ground saturated and setting the stage for a historic event, says Kreienkamp. Rain on the day of the floods was heavy but not extreme – 100 to 150 millimetres – but it was too much for the valley.

DAVID KLAMMER/LAIF



Clockwise from above: A message for volunteers in Rech near the Ahr river, Germany; remains of a broken bridge in Rech; rubble clearance in Dernau near the Ahr

Below: Alexandra Preste at Deutzerhof vineyard

Bottom: Markus Kelter in Walporzheim

DAVID KLAMMER/LAIF

The area's steep hills and flat floodplain amplified the impact. Water was funnelled through the valley, destroying more than 80 bridges, many of them formidable stone structures that were hundreds of years old. Travelling through the valley seven months on, you see that the skeletons of some bridges stand by temporary pontoons. Railway tracks remain swept away; piles of wood, mud and other debris stand by the roadside; and high watermarks remain above ground-floor height on many buildings.

Despite these lasting scars, a colossal recovery effort is under way. Alongside an army of official contractors rebuilding roads and infrastructure is a movement of volunteers, with many travelling from across Germany to help Ahr.

While there has been occasional hostility to these helpers – some are on an "ego trip taking selfies", says one local – they have also been welcomed, as the "Danke", "We Ahr Valley" and other messages daubed on damaged buildings attest. "This has been the biggest intervention in our history," says Sabine Lacker at the Federal Agency for Technical Relief, which coordinated nearly 17,000 volunteers in Ahr over six months.

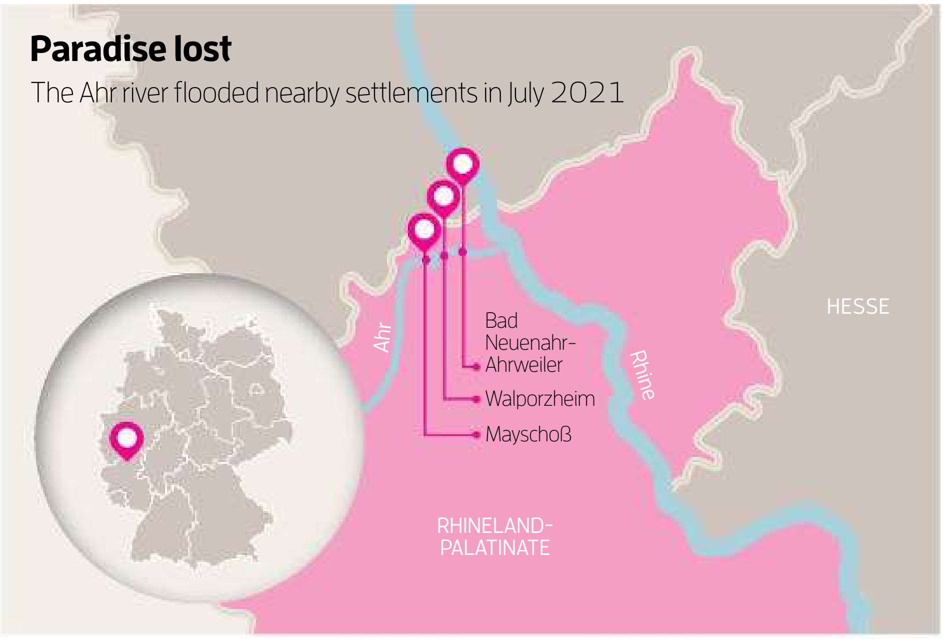
"We were a little paradise, with vineyards, a small river, bicycles. Then, one night, everything's gone"

However, much of the aid has been self-organised. Schultz-Coerne has been serving food at a makeshift canteen for more than 12 hours a day to volunteers clearing up around her village, Mayschoß. "It definitely was a way to help myself too," she says.

Thomas Putz, whose medical supplies business in Bad Neuenahr-Ahrweiler was flooded, responded by creating the "Helper Shuttle", using social media to rapidly coordinate thousands of volunteers. The aid involved not just clearing mud and debris, but also helping people who were grieving. "We don't only need your muscle, we need your ears," Putz told volunteers.

Guido Orthen, the mayor of Bad Neuenahr-Ahrweiler, says the challenge is long term. "The reconstruction of our city is a mammoth task," he says. Power and water were restored within weeks, schools have resumed and pop-up shops have been created. Nonetheless, he thinks restoring all infrastructure, from roads and lighting to parks and playgrounds, will take five to 10 years due to the sheer amount of damage. "We still have a long way to go," he says.

Meanwhile, questions are being asked about what lessons can be learned. "Germany seems to have been unprepared in terms of the disaster unfolding," says Alexander Fekete at Cologne University of Applied Sciences. The weather was forecast and early warnings issued to local authorities, but those didn't always make it down to officials and residents in Ahr, says Fekete (see page 25). A mobile phone broadcasting system went unused and there were no sirens when the floods hit: Putz resorted to throwing sandbags at buildings to wake people in the night.



Paradise lost

The Ahr river flooded nearby settlements in July 2021

While some people have left in the flood's aftermath, several tell *New Scientist* they are committed to the area. Leonard Kneips, a young construction worker temporarily staying in a "tiny house" while he waits for his flat in Mayschoß to be renovated, says he will stay. He is fatalistic about the prospect of more floods as the world warms. "If it happens, it happens," he says.

Researchers agree that the risk of flooding in Europe is increasing. Warmer air holds more water and climate change may also be increasing the chance of weather systems getting "stuck" like they did last July, due to a weakening of the jet stream. But that is still just a hypothesis, says Friederike Otto at Imperial College London.

The events have shown that even with today's level of warming – about 1.1°C globally since the industrial revolution – adaptation will be hard and sometimes impossible in high-income countries, let alone poorer ones. There is little Ahr could have done to prepare for these freak floods. "It showed that everyone is affected by climate change. Sometimes we think, in Europe, we are rich and can deal with it," says Elco Koks at the Free University of Amsterdam.

A mixed picture

Ahr's recovery offers a mixed picture on future-proofing homes for more extreme weather or to contribute less to climate change. Some houses' oil-based heating systems, which spilled and contaminated water during the floods, are being swapped for lower-carbon options. But in most cases, homes are being rebuilt with little sign of adaptation, such as moving living areas above the ground floor.

Nonetheless, last July's events have influenced the discourse on climate change nationally. "This event changed everything," says Enno Nilson at the German Federal Institute of Hydrology. He says there is now a big focus on flood risk in addition to drought, which had been the main area of discussion for climate impacts in Germany, following wrecked harvests in 2018.

The floods have changed how people think in Ahr, too. Alexandra Preste at Deutzerhof vineyard says the valley's topography used to make people feel safe, and the floods flipped that. "I felt we were living in the promised land. It's like we've lost our innocence," she says. But that could lead to more climate action, she says. "People only change their behaviour when they see something." ▌

A road map for adaptation

Scientists in Working Group II (WGII) of the Intergovernmental Panel on Climate Change are currently agreeing the final version of a landmark report on the impacts of climate change and how we might adapt to them. This is the second of four documents comprising the sixth in a series of "assessment reports". The first document, published last year, found that humanity's role in warming to date was "unequivocal". A third, due in early April, will focus on how to avert catastrophe by curbing emissions and removing carbon dioxide from the air. The fourth, to be published in September, will synthesise the previous three.

Debra Roberts, a co-chair of WGII, says the report will have a more detailed regional breakdown of impacts than in the past because "people respond to places they know". A stronger focus will be given to climate impacts in cities, such as heatwaves. More emphasis will be placed on the differing vulnerability and exposure of people around the world, depending on their ability to pay for ways to adapt. The report is also expected to highlight the "implementation gap" between what researchers say needs to be done – from better flood defences and planting new crop varieties to cooling cities with trees – and what is happening in reality.

Animal behaviour

Rats can track the passage of time and judge their accuracy

Carissa Wong

RATS can time their actions to gain a reward – and they can judge how accurately they performed.

To explore rats' abilities to track time, Tadeusz Kononowicz at the Polish Academy of Sciences and his colleagues trained 16 rats either to leave 3.2 seconds between presses of a lever or to hold the lever down for this length of time.

Once the rats consistently produced responses very near to the 3.2-second target, the researchers gave them a way to report on their accuracy. This was achieved by using two "reward ports".

The precise leeway each rat was given for its timekeeping during the testing depended on its training performance. In each test, if the animal was judged to be close to the target time – within about 250 milliseconds, on average – it had the option of poking its nose into the port on the left to receive two food pellets. There were no pellets in the right port.

> "Our results add a whole new richness to the way that rats represent time in their minds"

However, if the rat's timing was judged to be less precise – if it was off by around 500 milliseconds, on average – the left port no longer delivered a reward. But the rat could still get one food pellet from the port on the right.

The team found that rats that had been precise enough with their timing approached the left port for a large reward more than 60 per cent of the time. Those that had been less precise approached the right port for a small reward more than 60 per cent of the time (*PNAS*, DOI: 10.1073/pnas.2108850119).

"Our results add a whole new richness to the way that rats represent time [in their minds]," says Kononowicz. ▮

Agriculture

Covering plants with red plastic boosts crop yields

Alice Klein

THE yields of some crops can be boosted by covering them in a material that increases the amount of red light they receive. This technology could help feed the world's growing population, although more research is needed to see if it affects the flavour and nutrition of plants.

Red wavelengths of sunlight are the biggest drivers of plant growth because they stimulate leaves to make the chlorophyll needed for photosynthesis. This is why some farms have started shining red LED lights on crops to boost their yields. But these are costly, energy-draining and don't distribute light as evenly to plants as sunlight.

To address these issues, Alexander Soeriyadi and Alexander Falber at the University of New South Wales in Sydney, Australia, developed a material called LLEAF that passively converts some of the green wavelengths in sunlight – which are less important for plant growth – to red ones.

It is a transparent plastic containing a fluorescent dye that absorbs green wavelengths of sunlight and re-emits them as red ones. LLEAF can be hung over existing greenhouses and creates a soft pink light inside. "It's quite pretty," says Soeriyadi.

In greenhouse trials, the researchers found that the material increased plant yields by an astonishing amount for various crops, including 37 per cent for pak choi. The material is now being tested in bigger, independent trials run by Western Sydney University and the New South Wales government's Department of Primary Industries.

David Tissue at Western Sydney University and his colleagues recently completed a trial of the material. They installed it over a greenhouse to cover a 200-square-metre plot of lettuces next to an identical plot of lettuces that wasn't covered by LLEAF. The yield of cos lettuce, also known as romaine, rose by 14 per cent under the material, while that of butterhead lettuce increased by 27 per cent.

Tissue is now testing LLEAF on cucumbers, with plans for several other crop trials over the next five years. The Department of Primary Industries is trialling it with blueberries, but results aren't available yet.

One important consideration is whether taking green light from plants and giving them extra red light might harm them, says Tissue. He noticed that lettuces grown under the material had an orange tinge, probably because the altered sunlight changed their composition of carotenoids and other pigments. "But we need to do further research to see if this changes the flavour or nutrition," he says.

37%

Increase in pak choi yields when grown under red plastic

Robert Coe at CSIRO, Australia's national science institute, says it is also unclear how well the technology would work for other types of crop, like cereals. "But I think it's worth exploring," he says.

Soeriyadi and Falber are now developing a library of dyes to tailor their material to different crops. They hope that boosting crop productivity will help meet growing food demand, which is expected to increase by up to 56 per cent globally from 2010 to 2050.

By manipulating the light that plants receive, they believe it may even be possible to grow crops in parts of the world that don't normally suit them, if other variables like temperature and humidity are also controlled. ▮

ALEXANDER SOERIYADI/LLEAF PTY LTD

LLEAF is a transparent red plastic that absorbs green wavelengths

ATEM Mini Pro model shown.

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Medicine

Lung changed to new blood type is a step towards universal donor organs

Alex Wilkins

RESEARCHERS have successfully changed the blood type of a donated human lung by treating it with enzymes, marking an important step towards making universal donor organs.

"We still have a way to go to show safety in clinical trials," says Marcelo Cypel at the University of Toronto, Canada. "But assuming that the results on clinical trials are similar to the results we observed here, this will be a major breakthrough."

Blood types are largely defined by the presence or absence of certain sugar molecules called antigens on the surface of cells. These can occur not just on the cells of the blood itself, but also other tissues, such as those in the lung. If an antigen isn't recognised by the body's immune system, it will mount an attack on these cells. This leads to the rejection of transplanted organs from a donor with a different blood type.

People with the most common blood type, O, lack these antigens on their cells, so their organs can be accepted by people with other blood types. If all donor organs could be made type O, for example the lungs from someone with blood type A, this could be a help.

To try this, Cypel and his team used a pair of enzymes that are normally found in the human gut to digest sugars. They found that the enzymes removed more than 99 per cent of type A antigens from red blood cells and 97 per cent in lungs from a type A donor in 4 hours. This meant the cells had been effectively changed to blood type O.

After this treatment, the altered lungs were kept alive using a system known as ex-vivo lung perfusion, which supplies organs with nourishing fluid so they are ready for transplantation.

To simulate a transplant, Cypel's team then added type O blood, which contains antibodies that would attack type A antigens, to the fluid supplying the lungs. The three treated lungs had minimal antibody damage compared with untreated lungs (*Science Translational Medicine*, doi.org/gphgf5). "When we perfused the lung with old blood, there was no sign of rejection or organ dysfunction," says Cypel.

UNIVERSITY HEALTH NETWORK

A researcher with a system to deliver fluid to lungs in the study

Although cells stripped of antigens tend to produce new ones over time, Cypel hopes that the lack of antigens would last long enough for the body to get through the perilous first few days and weeks after a transplant. The team now intends to test the procedure in animals.

The study only looked at the effects of a simulated transplantation over the short term, which isn't enough time to assess whether the resurfaced antigens could eventually have a negative effect, says Jasvir Parmar at Royal Papworth Hospital, Cambridge, UK. "We can't [yet] say whether re-exposure of these antigens or the changes that come with that are going to be deleterious in the long run or not," he says. ▮

Technology

Driverless car photos used to create virtual San Francisco

SOFTWARE can analyse millions of photos of city streets taken atop cars and construct a realistic 3D model that could be used to train driverless cars or create immersive maps.

Block-NeRF was created by a team at driverless car firm Waymo and Google Research, which are both owned by Alphabet. The tool uses vast numbers of photos taken by cameras mounted on Waymo's autonomous cars and builds numerous small 3D models, each covering just over one city block. These are then seamlessly stitched together to create a large and navigable virtual world.

The researchers declined to be interviewed, but said in a paper that their work builds on a tool called Neural Radiance Fields (NeRFs), which constructs 3D models of small objects from a collection of still images so that they can be viewed from any angle – even those for which no photos were taken. The technique uses an AI trained to produce accurate 3D models from large sets of images, complete with information on the exact location in which each image was taken.

The models are computationally intensive to create and run, and until now they have been limited in the size of the objects they can reproduce in virtual 3D. But Block-NeRF cleverly stitches together models of individual city blocks to keep the size of the overall model small enough to run on modest hardware. New blocks are recalled from memory when needed.

2.8m

Number of images used to recreate a neighbourhood in San Francisco

In a recreation of the Alamo Square neighbourhood in San Francisco, California, which is around 960 metres by 570 metres, the team used 35 Block-NeRFs. To do so, it used 2.8 million images, taken over three months.

Because those drives were made at different times of day and in different weather, the tool is able to change the virtual conditions at will from any location – making the scene night-time or daytime, cloudy or sunny (arxiv.org/abs/2202.05263). ▮

Matthew Sparkes

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Climate change

A substitute for whale poo

Whaling left oceans with less of the animals' faeces, which drives algal blooms that lock away carbon. Now scientists are trying to mimic this process, reports **Adam Vaughan**

AN INTERNATIONAL project to see whether humans can artificially emulate the benefits of whale faeces for ocean ecosystems will begin off the west coast of India within the next two months. The hope is the technique will simultaneously boost fish populations and tackle climate change.

The experiment is the first in a wider effort by David King, former chief scientific adviser to the UK government, and a coalition of six universities and research centres to test the potential for an approach they have dubbed marine biomass regeneration.

Whales naturally fertilise the ocean surface when they defecate, leading to phytoplankton blooms that can feed billions of fish.

Improving biodiversity is the main aim of the approach, but a side benefit will come from the phytoplankton absorbing carbon dioxide from the atmosphere. When fish eat the plankton and die, some of the carbon will be locked away in the seabed. Marine biologists call this effect a biological pump. The hunting of whales in the past century has weakened this ecosystem service.

"We are trying to repopulate the ocean," says King, who now heads the Centre for Climate Repair at Cambridge, UK. "I don't know whether the experiment will be the final answer. I'm very attracted to the idea that after a while… if the whale population [recovers], we can leave the whales as the biological pump."

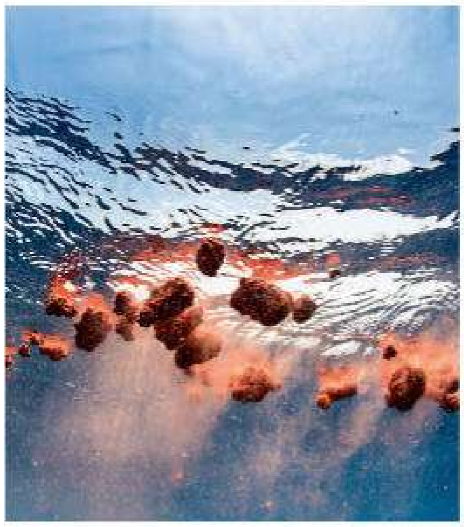
Precisely what the artificial whale faeces will be made of is yet to be decided, but iron-rich sand or volcanic ash are two options being considered. Key will be ensuring it offers the right mix of nitrates, silicates, phosphates and iron, says King. The material will be loaded onto baked rice husks – a factory waste product – which will act as rafts to carry the material on the sea surface.

REINHARD DIRSCHERL/ALAMY

Sperm whales fertilise the oceans when they defecate

"Key will be ensuring the fake faeces has the right mix of nitrates, silicates, phosphates and iron"

Faeces from a pygmy blue whale floating in the Indian Ocean


NATUREPL.COM/ALAMY

To comply with the London Convention, a treaty that covers the dumping of matter in the oceans, King says the "very limited experiment" will be small-scale and will last just three weeks or so. The main aim is to see whether the rice husks are a good way of delivering the artificial faeces.

The timing of the experiment will depend on the weather, but it will mark an important first step for King, who has previously said that similar approaches could lock billions of tonnes of carbon dioxide away each year. Humanity emits about 40 billion tonnes a year, so it is likely that we will have to remove large amounts of greenhouse gas from the atmosphere to avoid ever-more dangerous warming under climate change.

Biomimicry, or aping natural processes, is at the heart of King's approach. He says that what the researchers are doing shouldn't be conflated with geoengineering, or large-scale interventions in Earth's climate systems, such as efforts to block solar radiation. But he acknowledges that for marine biomass regeneration to make a difference to fish numbers and carbon removal, it will need to be undertaken at huge scale.

The group that is exploring the approach is made up of the University of Hawaii and Woods Hole Oceanographic Institution in Massachusetts, which are leading on research in the Pacific Ocean, the Institute of Maritime Studies in Goa, India, on the Indian Ocean, the University of Cape Town on the Southern Ocean, and the University of Cambridge and the UK's National Oceanography Centre on the Atlantic Ocean.

Help for island economies

Together, the group will explore the challenges of restoring the role played by whale faeces, plus issues around governance and public attitudes. "As long as there's no potential harm to the oceans, we believe these experiments need to be conducted," says King.

If the idea of artificial whale faeces can be shown to work safely at scale, King thinks one economic model could be coastal and island communities paying for it to boost fish catches.

Other researchers are exploring the idea of mimicking whale faeces to capture carbon. Australian researchers, calling themselves WhaleX, dispersed a mix of nutrients about 10 kilometres off the coast of Sydney last December. They are planning larger-scale demonstrations in a bid to win a share of the $100 million XPrize Carbon Removal contest.

Edwina Tanner at WhaleX says of their and King's plans: "It is great to finally see… experiments are being conducted to support our hypothesis." ▮

Biology

Ancient 'fossil' virus found in the human genome

Michael Le Page

AROUND 106 million years ago, the DNA of a virus somehow got integrated into the genome of one of our mammal ancestors. Two million years later, something similar happened again with the same kind of virus. Now, the ancient remnants of that virus have been found inside our cells.

Our genomes are strewn with "fossil" viruses, but almost all are retroviruses, which actively insert DNA copies of their RNA genes into the genomes of the cells they infect.

If this occurs in cells that give rise to sperm or eggs, the virus-derived DNA can be passed down the generations. Over time, the viral genes mutate and eventually can't lead to infectious viruses. Between 5 and 10 per cent of our genome consists of retroviral remnants.

The newly discovered virus instead belongs to an ancient group of DNA viruses called Mavericks. Fossil Mavericks have been found in various animals, including fish, amphibians and reptiles, but until now had never been spotted in mammals (bioRxiv, doi.org/hg94).

Aris Katzourakis and José Gabriel Niño Barreat at the University of Oxford think these viruses plagued mammals from the time these animals first evolved around 180 million years ago during the Jurassic Period until at least 105 million years ago during the Cretaceous Period, when the insertions took place.

After that, Mavericks appear to have died out in mammals for reasons that aren't clear. They might still infect other animals, such as fish, but, as yet, no free-living Mavericks have ever been found.

"There aren't that many non-retroviral viruses in our genome," says Katzourakis. "This is the only DNA virus in the human genome that we know of, and it's certainly the oldest non-retroviral insertion in our genomes."

Analysis Cybercrime

Crackdown on cryptocurrencies

The launch of specialist teams to tackle blockchain crimes and scams shows the issue has become too big to ignore, says **Chris Stokel-Walker**

THE profile of cryptocurrencies such as bitcoin has continued to rise, including as a method to pay for goods and services in the mooted next generation of the internet, Web3. But as more money pours into the so-far loosely regulated currencies, government scrutiny is also increasing.

On 17 February, the US Justice Department announced that it was launching a National Cryptocurrency Enforcement Team (NCET) to monitor blockchains, the underlying technology behind cryptocurrencies, for any ill-gotten gains. It will work with various groups, including the FBI's newly launched Virtual Asset Exploitation Unit, which also focuses on cryptocurrency.

"With the rapid innovation of digital assets and distributed ledger technologies, we have seen a rise in their illicit use by criminals who exploit them to fuel cyberattacks and ransomware and extortion schemes; traffic in narcotics, hacking tools and illicit contraband online; commit thefts and scams; and launder the proceeds of their crimes," said Kenneth Polite Jr from the US Justice Department in a statement.

The news comes weeks after the department charged a couple with laundering bitcoins worth $4.5 billion, and just after the UK tax authority, HMRC, announced its first seizure of non-fungible tokens (NFTs), digital assets that are paid for with cryptocurrencies. And in January, a *New Scientist* investigation revealed that UK police forces have seized £300 million in bitcoin in the past five years.

Taken together, it seems to add up to a cryptocurrency crackdown. "This is excellent news for anyone who has been watching the space for a long time, and is long overdue," says Andres Guadamuz at the University of Sussex, UK. "There's always been fraud in crypto indeed, but I think that there is growing concern about the scale of some of the frauds."

While there are many legitimate uses for the technology, cryptocurrencies are also used for money laundering and other illicit financial transactions. A recent analysis of 29 unregulated cryptocurrency exchanges, where people can trade the currencies, found that up to 70 per cent of cryptocurrency trades were "wash trading" – where an investor sells and buys the same asset to create artificial interest in an investment, often distorting the price.

That research studied exchanges up to 2019. A more recent analysis, conducted by blockchain data platform Chainalysis, estimates that at least $25 billion in cryptocurrency held on exchanges is from illicit sources. That compares with estimates of money laundered every year worldwide of between $800 billion and $2 trillion.

"The FBI, along with many other law enforcement agencies, have made no bones about the fact that they see cryptocurrency – and bitcoin in particular – as the favoured means of monetising crimes, especially the ever-increasing scourge of ransomware," says Alan Woodward at the University of Surrey, UK.

Bitcoin has long been seen as a useful tool for criminals and scams

SHUTTERSTOCK/COYZO

At the same time, cryptocurrency has broken out of an online niche and is now seen as a more mainstream investment. Large cryptocurrency exchanges ran adverts featuring Hollywood stars during the Super Bowl on 13 February, one of the world's most-watched sporting events.

1000%

Rise in value of cryptocurrency scams from 2020 to 2021

While cryptocurrency exchanges are legitimate businesses, the increased prominence of the technology makes it easier for people to fall victim to scams. "Cryptocurrency scams and other crimes are impacting more and more people in a plethora of different ways," says Matthew Shillito at the University of Liverpool, UK.

In May 2021, the US Federal Trade Commission (FTC) said it saw a 12-fold increase in the number – and 1000 per cent rise in value – of reported cryptocurrency scams, compared with a year before. The volume of scams rose significantly throughout 2020 and 2021, the FTC said.

In a sense, the creation of the NCET is an acknowledgment that cryptocurrencies are set to play an increasingly important role in the US economy, and therefore must be policed as such. "The instability and fraud have been tolerated until now, but as more and more people sink their savings into crypto, the danger of collapse is more real," says Guadamuz.

Neuroscience

We may be unable to grow new brain cells after we enter adulthood

Jason Arunn Murugesu

ADULTS may not be able to create new neurons in the brain – contrary to previous findings.

The question of whether adults can form new neurons, called neurogenesis, has long been a source of controversy. While researchers have discovered adult neurogenesis in mice and macaques, the evidence for this ability in humans is less clear.

The hippocampus, which has been linked with adult neurogenesis, is vulnerable to Alzheimer's disease and other neurodegenerative conditions. This has led to arguments that adult neurogenesis may hold the key to treating these conditions.

Jon Arellano and Pasko Rakic at Yale University and their colleagues examined the brains of six deceased people, with an average age of 53, who had donated the organ to science. They also studied the brains of seven macaques and 18 pigs, and looked at data from studies of mouse brains.

"There are two regions where neurogenesis occurs [in non-human animals]," says Arellano. "One is the olfactory bulb and the other is the hippocampus."

The human olfactory bulb, which is vital for our sense of smell, is considered incapable of adult neurogenesis, says Arellano, but there is still debate when it comes to the hippocampus.

The researchers used a technique called single-nucleus RNA sequencing to study the hippocampal cells in the brain samples. This method targets the nuclear RNA molecules that help turn DNA code into proteins and can characterise the cell, which can help establish its age.

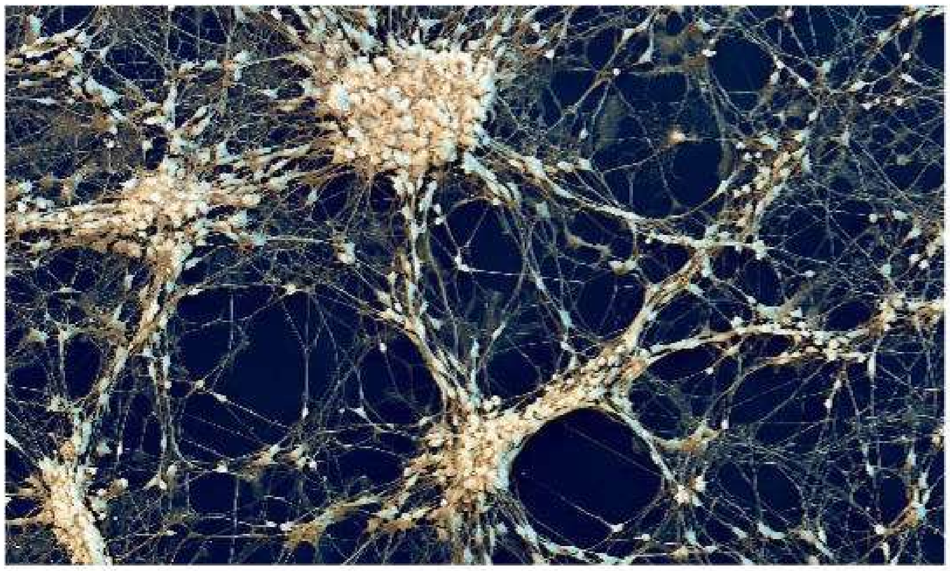
They found that just 0.003 per cent of their human sample cells had a nuclear RNA profile that suggested they were newly created neurons. For comparison, about 6.6 per cent of the cells in the same region in mice and 2 per cent in macaques could be new neurons.

The researchers also looked in their brain samples for DCX, a protein marker for newly formed neurons. Other studies have found DCX in the human adult hippocampus, but Arellano argues their methods were unreliable. Using a more fine-tuned technique, he and his team didn't find any of this protein in their samples. Combined with the nuclear RNA data, this suggests to them that adult neurogenesis doesn't exist in humans (*Neuron*, doi.org/gnmgrb).

If they are right, that makes the human brain truly remarkable, says Rakic. "I'm over 88 years old and I have billions of neurons that have lasted a lifetime," he says. "That's more impressive to me than the idea that mice can make new neurons. Everything that I've learned is still there in my brain."

Sebastian Jessberger at the University of Zurich in Switzerland thinks it is too soon to conclude that adult neurogenesis doesn't occur. "The paper now shows absence of evidence, using their approach for single-cell isolation and data analyses," he says. "But that absence of evidence certainly is not proof for the absence of neurogenesis."

Neural progenitor cells, precursors of neurons, grown in the lab



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Medicine

Map of pain neurons may lead to more effective drugs

A NEW atlas of pain-sensing neurons in the body could help in the development of improved treatments for chronic pain.

Chronic pain, defined as that lasting 12 weeks or more, affects between one-third and a half of all adults in the UK. It is more prevalent in older groups. Finding new treatments and therapies is becoming more urgent as the world's population ages.

"A lot of pain studies have been conducted in mice and there's been some lack of translation when it comes to looking for drug targets for humans," says Diana Tavares-Ferreira at the University of Texas.

To learn more about the differences between species, she and her team mapped the pain neurons in eight deceased people who had donated their bodies to science and then compared these findings with data from mice and macaques.

The team used a method called spatial transcriptomics to determine which genes were active in each cell. This showed that pain neurons in humans seem to be geared to respond to all kinds of pain, such as heat or mechanical pain, whereas rodent pain neurons are more specific (*Science Translational Medicine*, doi.org/hg6d).

The researchers also looked at sex differences in the human samples. "We found that there's probably more differences in the underlying mechanisms that promote chronic pain between male and female humans compared to sex differences in rodent models," says co-author Theodore Price, also at the University of Texas.

Identifying which proteins are involved in generating different types of pain is an important step towards new drugs, and this map will help researchers do that, says Peter McNaughton at King's College London. "This study is among the first to use human sensory neurons," he says. "It is certain to act as a reference work – a sensory neuron atlas – for years to come."

JAM

"A lot of pain studies have been conducted in mice and there's been some lack of translation to humans"

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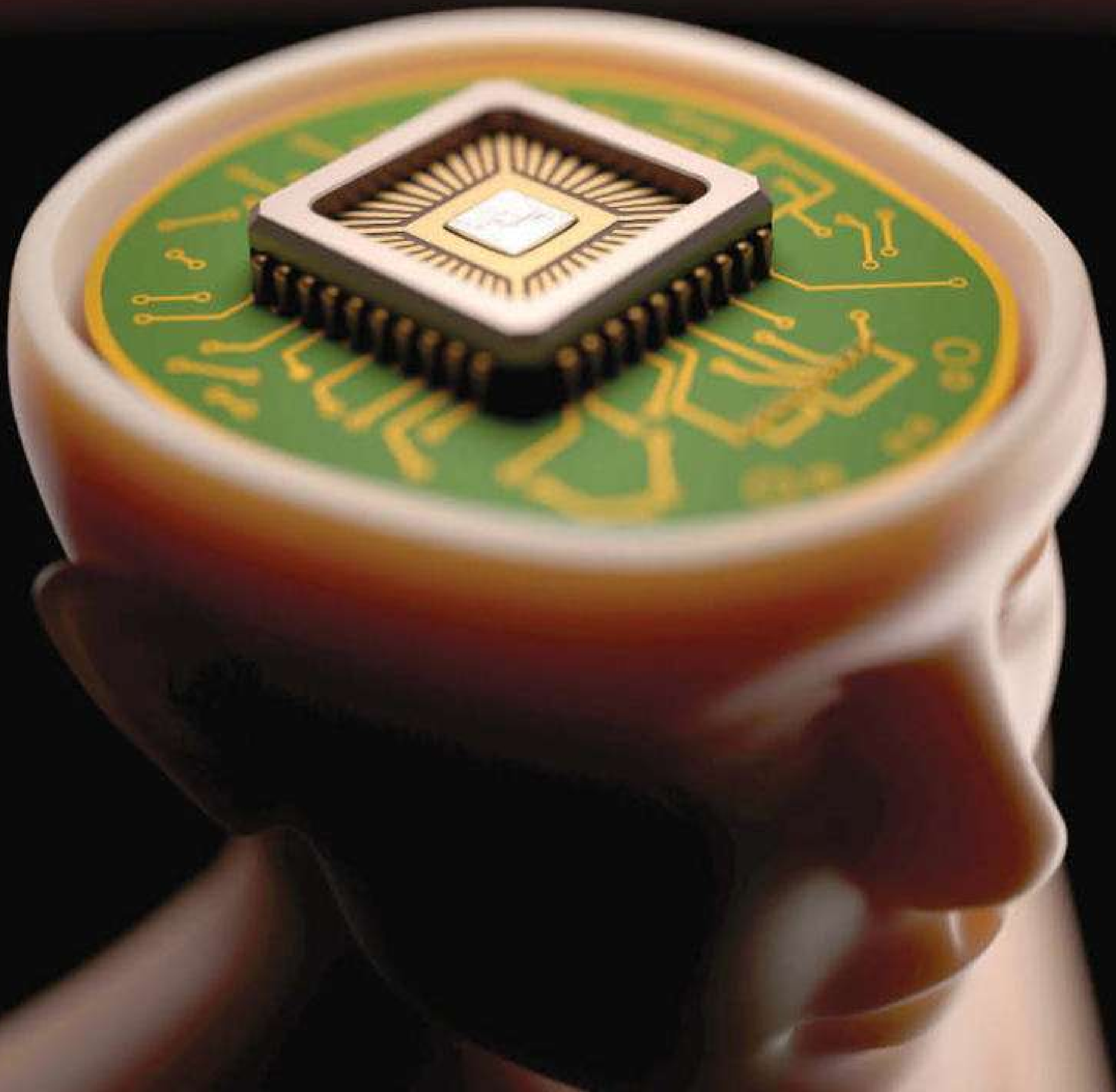


Energy

AI brings fusion power closer

Tech firm DeepMind has created a neural network that keeps the super-hot plasma inside a fusion reactor under control, reports **Matthew Sparkes**

FUSION reactors promise cheap, abundant and relatively clean energy – if we can get them to work. Now, thanks to artificial intelligence firm DeepMind, fusion researchers are one step closer to extracting power from plasma that is hotter than the sun.

DeepMind worked with scientists at the Swiss Federal Institute of Technology in Lausanne (EPFL), Switzerland, to create a neural network capable of controlling the magnetic fields within EPFL's Variable Configuration Tokamak (TCV) fusion reactor.

These magnetic fields are essential for keeping the plasma generated by the reactor safely contained. If the plasma touches the walls of the reactor, it rapidly cools, stifling the reaction and potentially causing significant damage to the vessel.

Researchers at the TCV previously used 19 magnetic coils, each controlled by a separate algorithm that monitored the interior of the reactor thousands of times a second with a host of sensors. DeepMind instead created a single neural network to control all the coils at once, automatically learning which voltages needed to be supplied to them to best contain the plasma.

The team trained the AI on a precise digital simulation of the reactor before conducting experiments on the real machine. Ultimately, it was able to successfully contain the plasma for around 2 seconds, which is approaching the limits of the reactor – TCV can only sustain the plasma in a single experiment for up to 3 seconds, after which it needs 15 minutes to cool down. The record for fusion reactors is only 5 seconds, set recently by the Joint European Torus in the UK.

DEEPMIND; CURDIN WÜTHRICH/SPC/EPFL

The TCV fusion reactor and, inset, plasma inside the device

As well as controlling the plasma, the AI was able to shape it and move it around within the reactor. New plasma shapes may bring efficiency or stability improvements in new fusion reactors such as ITER, which is currently being built in France. It will be the world's largest tokamak, a doughnut-shaped reactor, when complete in 2025. The AI was also able to control two separate beams of plasma at once (*Nature*, doi.org/gpg9dn).

Federico Felici at EPFL says that although there are many theoretical approaches that could be used to contain the plasma with a magnetic coil, scientists have tried-and-tested strategies. But the AI surprised the team with its novel approach to forming those same plasma shapes with the coils.

"This AI algorithm, [through] reinforcement learning, chose to use the TCV coils in a completely different way, which still more or less generates the same magnetic field," says Felici. "So it was still creating the same plasma as we had expected, but it just used the magnetic coils in a completely different way because it had complete freedom to explore the whole operational space. So people were looking at these experimental results about how the coil currents evolve and they were pretty surprised."

Gianluca Sarri at Queen's University Belfast, UK, says that AI is key to the future of control systems for fusion devices, which are currently aiming to sustain a reaction that produces more power than is consumed.

"Once this is done, this is not the end of the story. Then you have to make it a power plant," he says. "And this AI is, in my opinion, the only way forward. There are so many variables, and a small change in one of them can cause a big change in the final output. If you try to do it manually, it's a very lengthy process."

To make fusion reactors efficient, practical power sources, physicists need to increase the ratio between the pressure of the plasma and the power of the magnetic fields containing it, a value that is known as beta, says Howard Wilson at the University of York, UK.

"The plasma writhes and wiggles and tries to escape the clutches of the magnetic fields, and as one is pushing up that beta parameter, one is having to work harder and harder to get the control that one needs to just hold the plasma there," he says. "The further you push the plasma, the more chance you just suddenly lose it."

"The plasma writhes and wiggles and tries to escape the clutches of the magnetic fields"

Wilson believes these AI experiments show promise for containing plasma in "extreme geometries", which could lead to improvements in stability or efficiency. "It makes the risky parameter space less risky to operate in, but also opens up new parameter space that we can go into and explore," he says. ■

Synthetic biology

DNA reveals if drinking water is safe

An engineered version of the double helix forms part of a device for detecting pollutants

Matthew Sparkes

A BIOLOGICAL computer controlled by DNA offers a cheap and simple way to test the concentration of contaminants in drinking water.

Julius Lucks at Northwestern University in Illinois and his colleagues created a biosensor in 2020 that can detect contaminants in a drop of water. It contains proteins that react to the presence of certain chemicals by producing fluorescent molecules, warning that a water sample is polluted with these chemicals.

The reactions involved were inspired by mechanisms that evolved naturally within bacteria. Lucks says that scientists initially tried engineering the bacteria to carry out the tests, but it was a challenge to keep them alive and stop them from spreading into the environment. This led to research into a cell-free, synthetic biological version, where the protein-based mechanisms are removed from the bacteria and used in isolation.

"In synthetic biology, we're trying to repurpose molecular machines and re-engineer them so they work how we want them to," says Lucks.

Now, the team has created a more advanced version of the system that can not only warn of the presence of dangerous chemicals in water, but can also use computational logic operations to calculate and report on the amount it contains, so proportionate steps can be taken.

The system, dubbed ROSALIND 2.0, has eight small test tubes, each containing a biosensor with a different sensitivity to a particular contaminant. If only one tube glows, then the water sample has just trace levels of contamination. But as more tubes fluoresce, the water is shown to be increasingly more polluted.

The test works by using "decoy" strands of DNA. These are designed to bind strongly to a key intermediate product in the reaction with the contaminant, preventing production of the fluorescent molecule.

"The DNA means the system can report on the amount of dangerous chemicals in water"

Each tube – into which a sample from the same water source is added – has progressively larger quantities of this DNA. Because the fluorescent step of the reaction only occurs after all the decoy DNA has been used up, this means a tube with a low amount of DNA may glow in the presence of the contaminant, but one with lots of this DNA may not. It is possible to measure the level of the contaminant simply by seeing how many tubes are fluorescing.

Lucks and his team showed that ROSALIND 2.0 successfully detects zinc, an antibiotic and an industrial metabolite (*Nature Chemical Biology*, doi.org/hg7n).

"Everybody should have these things," says Lucks. "You should know your water is safe to drink."

The researchers also performed further experiments showing that the engineered DNA can carry out a wider range of logical operations, offering the potential for more advanced computation.

They say that not only could a future device be made to react to the presence of one material, as in ROSALIND 2.0, but they believe one could be built to react only when two specific chemicals are found. ▮

Ecology

Invasive poisonous toads may be killing Madagascan snakes

FEARS about the impact of invasive, poisonous toads in Madagascar appear to be justified. The amphibians seem to be behind a spike in deaths of a native snake.

Asian common toads (*Duttaphrynus melanostictus*) are native to southern Asia, but were brought to eastern Madagascar around 2010, probably as stowaways on a ship. Since then, the toads have been spreading from the point of arrival by about 2.5 kilometres per year, prompting anxiety that they could threaten Madagascar's native wildlife.

Angelica Crottini at the University of Porto in Vairão, Portugal, and her colleagues were interested in the toads' movement patterns, since it wasn't known if they could infiltrate patches of forest. Working near a forest close to the Madagascan seaport town of Toamasina, the team fitted eight toads with radio transmitters and tracked them, finding they did in fact get into the forest.

FULVIO LICATA

An Asian common toad (*Duttaphrynus melanostictus*)

During this work, team member Fulvio Licata, also at the University of Porto, noticed carcasses of native Malagasy cat-eyed snakes (*Madagascarophis colubrinus*).

It is rare to find carcasses while working in humid tropical regions, says Crottini, since they decompose rapidly. The researchers suspected the toads were responsible as they found more dead snakes, sometimes with dead toads nearby or in the snakes' mouths.

The team never found toads inside the snakes' gut, hinting that the toxins kill remarkably quickly (*Biological Invasions*, doi.org/hg7h).

"It was very sad to find the dead bodies of these beautiful native predators," says Crottini.

The team estimates that at least 5.7 per cent of the snake population was being killed by the toads every month. At this rate, the population could halve within a year, raising the risk it could soon be wiped out. ▮

Jake Buehler

Climate change

Oil giants accused of greenwashing over clean-energy switch

Adam Vaughan

FOUR of the world's biggest oil companies have failed to match their words on climate change with action, according to a study which concluded that the firms aren't seriously transitioning to low-carbon energy.

Gregory Trencher at Kyoto University, Japan, and his colleagues analysed the corporate reports, statements and spending of BP, Shell, Chevron and ExxonMobil. From 2009 to 2020, the companies' annual reports showed a clear increasing trend in the use of 39 keywords and phrases such as "climate change" and "transition".

But the researchers found a lack of concrete actions to meet targets for clean energy set over the period. Shell and Chevron have increased oil and gas production since 2015, and BP had too until 2020. All the firms spent only a tiny fraction of the billions they invest in energy projects each year on low-carbon projects (*PLoS One*, doi.org/gphdqw).

"Given the mismatch between discourse, pledges, actions and investments, aligning with recent studies, we conclude that no major [oil company] is currently on the way to a clean energy transition," the team wrote.

Responding to the study, a BP spokesperson highlighted the firm's post-2020 action on renewables and electric car chargers. A Shell spokesperson says: "We have always been clear that the business plans we have today will not get us to net zero. So, our plans must change over time." The other firms didn't respond to a request for comment. ▮

SHUTTERSTOCK/JAMES JONES JR

An oil rig at Cromarty Firth in Invergordon, UK

Physics

Time dilation seen on smallest scale ever in an atomic clock

Alex Wilkins

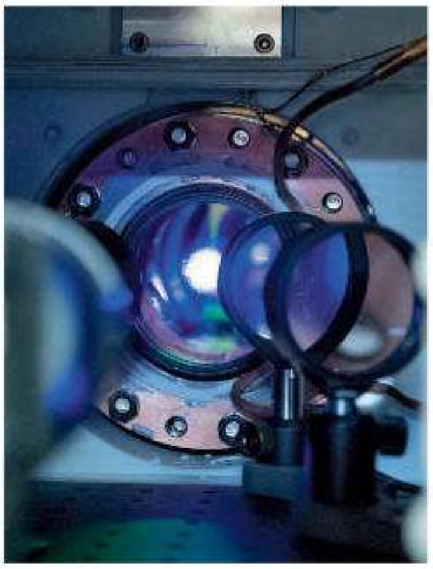
THE world's most precise atomic clock has confirmed that the time dilation predicted by Albert Einstein's theory of general relativity works on the scale of millimetres.

Physicists have been unable to unite quantum mechanics – a theory that describes matter at the smallest scales – with general relativity, which predicts the behaviour of objects at the largest cosmic scales, including how gravity bends space-time. Because gravity is weak over small distances, it is hard to measure relativity on small scales.

But atomic clocks, which count seconds by measuring the frequency of radiation emitted when electrons around an atom change energy states, can detect these minute gravitational effects.

Tobias Bothwell at JILA in Boulder, Colorado, and his colleagues separated hundreds of thousands of strontium atoms into "pancake-shaped" blobs of 30 atoms. They used optical light to trap these into a vertical stack 1 millimetre high. Then they shone a laser on the stack and measured the scattered light with a high-speed camera.

Because the atoms were arranged vertically, Earth's gravity caused the frequency of oscillations in each group to shift by a different amount, an effect called gravitational redshift. At the top of the clock, a second was measured as 10^{-19} of a second longer than it was at the bottom (*Nature*, doi.org/gphczn). This means if you were to run the clock for the age of the universe – about 14 billion years – it would only be off by 0.1 second, says team member Jun Ye at JILA.



JACOBSON/NIST

A stack of strontium atoms held in place with a laser

This redshift measurement, calculated to a certainty of 21 decimal places, was predicted by Einstein's theory. Previous measurements had observed the redshift over larger scales by comparing separate clocks, but the JILA team measured it in a single clock.

"This is the first time where, instead of comparing separate clocks over something like 30 centimetres, we're now looking within a single clock," says Bothwell.

10^{-19}

The increase in the length of a second over 1 millimetre

One reason for the clock's precision is because the groups of strontium atoms are close together and share environmental properties, such as their thermal environment, so can be more easily compared and imaged with JILA's high-resolution camera.

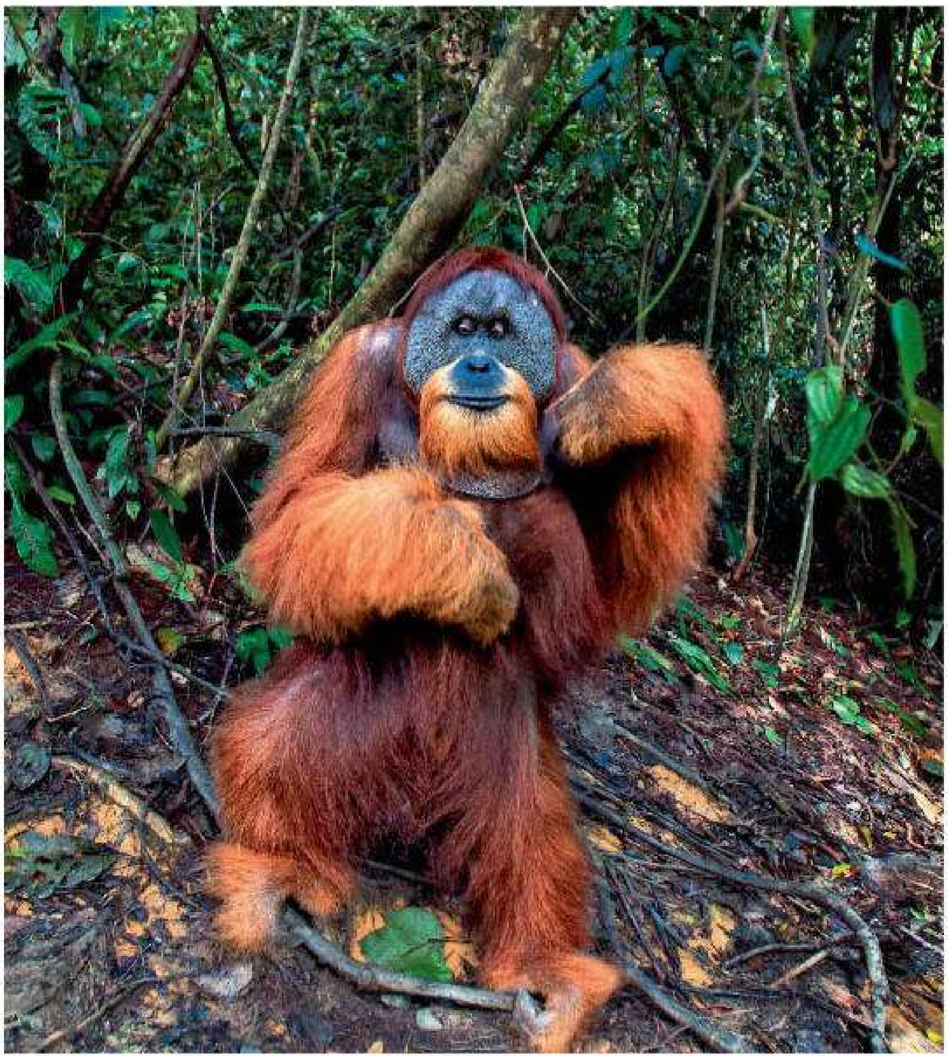
"It's a very impressive result that they've demonstrated. It's very interesting that, considering different parts of the apparatus, it might give you a different answer [as to the length of a second]," says Patrick Gill at the National Physical Laboratory, UK.

Bothwell says this atomic clock design could eventually be used to measure gravitational waves in space or the possible ways that dark matter couples to matter, as well as having uses in more practical areas, such as improving the accuracy of the Global Positioning System (GPS), which uses the precise timing of atomic clocks to calculate distance.

A group at the University of Wisconsin-Madison has also produced a new atomic clock set-up. Shimon Kolkowitz and his team used comparisons between six strontium atomic clocks to measure a second (*Nature*, doi.org/hg53). This comparative model, known as a multiplex clock, means the team can use a less stable laser but still achieve a very high level of precision.

"It's a nice demonstration that you can use lasers with much lower performance, which are more portable and more robust, and still do these kinds of clock comparisons, with pretty amazing levels of precision," says Kolkowitz.

He and his team's clock measures the relative differences between atomic clocks, so it is well suited to pinning down hard-to-measure effects that propagate through space, such as gravitational waves or dark matter. The group is now looking at measuring gravitational redshift using the multiplex clock on similar scales to the JILA team's clock. ▮



ANUP SHAH/NATUREPL.COM

Animal behaviour

Orangutans turn out to be naturals at using stone tools

CAPTIVE orangutans that had never seen stone tools have spontaneously picked up rocks and used them as hammers. One individual also used a sharp stone as a cutting tool.

The finding suggests that orangutans, which live in trees and rarely encounter stones, can figure out ways to use them. But there are limits: the animals never learned to make their own tools out of raw stone, even after being shown how.

Alba Motes Rodrigo, then at the University of Tübingen in Germany, and her colleagues studied two male orangutans in a Norwegian zoo. The apes were given a box containing a piece of fruit, sealed with rope. They were also given a concrete hammer and a lump of rock. In theory, the orangutans could have used the hammer to knock sharp flakes off the rock, and then used the flakes to cut the rope. But they didn't. The orangutans did hit things with the hammer, though.

In a follow-up experiment, Motes Rodrigo gave the orangutans a flint flake sharpened into an axe-like tool. "One individual, after trying to open the boxes in different ways, did get this sharp stone axe that I had made myself and used it to cut open the box," she says. "They can spontaneously, without any training, recognise that a sharp stone can be used for cutting and use it as such."

In another experiment, three other orangutans were shown how to make stone tools from a rock. But despite repeated demonstrations, they never managed it – although one did start hitting the lump of rock with a hammer (*PLoS One*, doi.org/hg6k). **Michael Marshall**

Palaeontology

Croc-like dinosaur's never-ending teeth

A NEWLY identified 8-metre-long predatory dinosaur probably waded in water to ambush fish and other prey with its crocodile-like jaws and its constantly renewing, serrated teeth.

Iberospinus natarioi represents a new genus and species of spinosaurid, a group of predatory dinosaurs. The spinosaurids are known for their long jaws, but they remain mysterious because few remains have been found.

Scientists originally thought that bones and teeth an amateur collector found on a western Portuguese peninsula in 1999 belonged to an already known spinosaurid. But in 2019, a different team studying the fossils noticed that the bottom edge of the lower jaw seemed too flat.

Inspired by those observations, Darío Estraviz-López at Nova University Lisbon in Portugal and his colleague Octávio Mateus at Lourinhã Museum in Portugal decided to re-examine the fossils. Their task was made easier because additional fossil bones belonging to the spinosaurid were uncovered in a 2020 excavation at the same site.

They scanned teeth and various bones, including parts of a jaw, a shoulder blade, a femur, a foot bone, a pubic bone and several vertebrae, mostly from the tail. It was clear the fossils didn't match descriptions and measurements of any known spinosaurid, says Estraviz-López. The jaw gave it a bit more of a crocodilian look.

The spinosaurid also had a unique pattern of nearly constant tooth eruption, with evidence that teeth grew in the jaw ready to replace those in use if they broke or were lost. While replacement teeth aren't uncommon in spinosaurids, this system would have allowed for a much faster turnaround time (*PLoS* One, doi.org/hg9r). **Christa Lesté-Lasserre**

Human behaviour

Swipe right if you like my immune system

MEN and women find the faces of people with higher-functioning immune systems more attractive.

Summer Mengelkoch at Texas Christian University in Fort Worth and her colleagues asked 159 men and women, averaging 20 years old, to pose for professional headshots in which they had neutral facial expressions and no make-up or jewellery. They asked these people about their health, and tested their blood and plasma to check their immune functions.

RAUL MELLADO/ALAMY

Next, they recruited another 492 men and women, averaging 25 years old, to rate 25 randomly selected photos. Heterosexual and homosexual participants were asked to rate the attractiveness of people of the opposite sex. The team found that people with higher ratings of attractiveness had higher rates of phagocytosis – essentially, of white blood cells that combat harmful bacteria.

In addition, women found men more attractive when they had higher-functioning natural killer (NK) cells in their plasma. The opposite, however, was true for men: men preferred women with lower levels of NK cells.

These cells can fight viruses and tumours, but research has also linked women's NK cell activity with lower oestrogen levels, and possibly lower fertility and higher rates of miscarriage (*Proceedings of the Royal Society B*, doi.org/hg6x). **CLL**

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Really brief

NMFS PERMIT 19225, FLIP NICKLIN/MINDEN PICTURES

Whales travel far in search of mates

Humpback whales may be far more mobile during their breeding season than previously thought. A study analysing crowdsourced photographs has revealed that some males travel up to 6000 kilometres between Mexico and Hawaii in less than two months (*Biology Letters*, doi.org/hg6m).

Our brains stay up to speed to age 60

The rate at which we process information during decision-making increases during our 20s and stays high until we reach 60, according to an analysis of data from 1.2 million people. The findings challenge the widespread belief that mental speed starts to decline in our 20s (*Nature Human Behaviour*, doi.org/hg9s).

Mosquitoes learn to avoid pesticides

Experiments show that two species of mosquitoes learn to avoid pesticides after just one exposure to a non-lethal dose. This suggests that changes in behaviour may be one way that mosquitoes can acquire resistance to these chemicals (*Scientific Reports*, doi.org/hg9t).

Society

Abortion opposition is flexible in the US

PEOPLE in the US who are morally opposed to abortion would still help a family member or close friend terminate a pregnancy if asked for support, according to a nationally representative survey.

Sarah Cowan at New York University and her team analysed data from the General Social Survey (GSS) to determine how views on abortion would affect the way a person would treat a friend or family member who asked for help with the procedure. The data was collected in 2018 and included answers from 1574 respondents.

Abortion is a divisive issue in the US. According to a 2021 Gallup poll, 49 per cent of adults there identify themselves as "pro-choice" and 47 per cent as "pro-life".

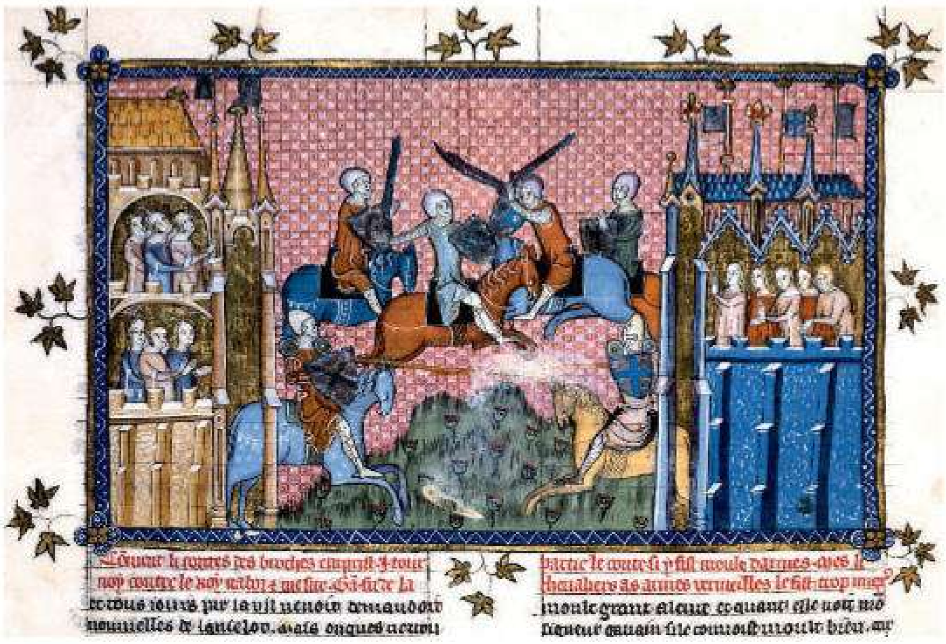
The team found that 88 per cent of GSS respondants, whether morally opposed to abortion or not, were willing to provide emotional support to a close friend or family member if that person was getting an abortion.

For those who were morally opposed to abortion, this number dropped to 76 per cent. Of this group, 46 per cent said they would offer a friend or family member logistical help, such as giving someone a lift, and 28 per cent said they would help with extra costs associated with the operation, such as travel or hotel fees. Six per cent said they would help pay for the procedure for a close family member or friend.

Over 50 per cent of those not morally opposed to abortion said they would help pay for the procedure (*Science Advances*, DOI: 10.1126/sciadv.abj5851).

Jason Arunn Murugesu

Modelling



THE PRINT COLLECTOR/ALAMY

Lost tales of age of chivalry quantified thanks to ecology

NINE in 10 medieval manuscripts telling tales of chivalry and heroism in much of Europe have vanished, according to a new estimate that drew on ecological methods to estimate what has been lost.

Katarzyna Anna Kapitan and Daniel Sawyer at the University of Oxford and their colleagues used the concept of the "unseen species model" to understand the volume of medieval literature in the genre of narrative fiction that once existed. Texts include stories of King Arthur and those of Lancelot (pictured).

An unseen species model is a statistical tool that ecologists can use to estimate biological diversity after surveying an area. The model taps into the number of observed species and their abundances to estimate how many extra species are present, but weren't spotted.

In the literature study, the researchers looked at the number of surviving copies of each manuscript, akin to the abundance of a species. They gathered records of 3648 copies of 799 works written in Dutch, French, Icelandic, Irish, English and German. The model suggested that these copies are part of a population that originally had 40,614 copies of 1170 works (*Science*, doi.org/hhkm). **Chris Stokel-Walker**

Technology

AI removes tattoos for face recognition

AN ARTIFICIAL intelligence can remove tattoos from photos of people's faces – potentially helping face recognition systems, which can be flummoxed by them.

In earlier research, Mathias Ibsen at Darmstadt University of Applied Sciences in Germany and his team identified that tattoos can impair the performance of face recognition systems.

They have now trained an algorithm to remove facial tattoos. This was done by automatically adding ink to 41 images of untattooed faces. The tattoos ranged in size, covering between 5 and 25 per cent of the face in the image.

Those computer-altered tattooed images were then used to train a generative adversarial network (GAN), a type of deep-learning algorithm. The GAN then removed the tattoo on the face – which it largely did without issue, except for very large tattoos.

The altered images were then tested against a face recognition system. The rate of errors, where the system either incorrectly matches two unmatched faces or fails to recognise a matched face, was halved when tattoos were removed by the GAN (arXiv, doi.org/hg64). **CSW**

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Culture
Enter the strange movie world of *Dual*, a clone thriller p31

Letters
Here's how to make the circular economy a reality p37

Comment

Failure of imagination

Creative thinking is at the heart of science, so why is there a lack of it when communicating some crucial findings, asks **Hannah Cloke**

SIMONE ROTELLA

IMAGINATION is one of those powerful human traits that sets us apart from other animals. By reading the word "circus", your brain automatically conjures up a rich tableau of images and ideas. But you don't need to be daydreaming of clowns to know that imagination plays a vital role in science.

The advancement of this domain intrinsically requires the birth of new ideas. Einstein famously claimed that imagination was more important than knowledge in the formulation of his theories. When researchers test ideas against reality, imagination is hardwired into the process: the point of science is that it allows you to see the future, to look round corners, to extend the capability of human insight. In that sense, imagination in science is alive and well.

But in another sense, it has an imagination problem. I recently gave evidence to two state-level inquiries in Germany into the July 2021 floods in the west of the country (see story on p8 for more on life after the floods). Both inquiries are exploring why almost 200 people died there in a deluge that was forecast accurately several days in advance. It is a complicated question that will probably yield many answers. I believe a lack of imagination may be partly behind this.

The scientists couldn't imagine that their forecasts, delivered in good time and with accuracy, could be ignored. Municipal authorities couldn't imagine that such dire forecasts might be correct. And many of the people living in harm's way just couldn't imagine what a 9-metre wall of water would do, or how badly they would be affected.

The best scientists use many of their human abilities – imagination and creativity, collaboration, communication and empathy – to make discoveries and reach new insights. Yet when it comes to telling people about them, we can turn into robots, unable to deliver important messages.

All of the most compelling ideas are those conveyed to us in ways that we can see and picture and feel. The big bang is a conceptual theory that no one needs to grasp to stay alive, yet it fundamentally changed the understanding of our existence. If physicists were able to describe it only to other physicists, humanity would be all the poorer.

Putting a human face on non-human phenomena can work too. There is good evidence that naming storms leads people to take action to protect themselves. In the UK, we have had plenty of exposure to this recently. The prospect of Corrie, Dudley or Eunice smashing into your home, as opposed to just seeing a generic warning of "gusts greater than 80mph", engages your brain in a way that encourages a response.

If naming storms works, then how about naming floods? Would people be more or less likely to respond to a warning and move to higher ground if a rising river was renamed Flood Dave? Such a label may be less accurate to hydrologists, perhaps, than saying that a rise in river levels of 5 metres will lead to flooding with a return period of 20 years. But probably more useful to everybody else.

As with the comet-spotting astronomers in the film *Don't Look Up*, or the real-life climate scientists that it is based on, it is a tragedy to see danger ahead when no-one acts to avoid it. The most advanced supercomputers running complex simulations are useless if nobody understands the risks that they foretell.

By ignoring imagination when we convey science, we are shirking our responsibility as scientists. If communicating our findings is important – and sometimes, lives depend on it – then we have a responsibility to undertake the task with as much flair, creativity and passion as we use when we do our research. Logic and reason is fine. But when we can't move beyond the facts, people may die. ▮

Hannah Cloke is a hydrologist at the University of Reading in the UK (@hancloke)

No planet B

Drowning in a sea of plastic Are we on the verge of a global initiative to clean up ocean plastics, or is it just more blah, blah, blah, asks **Graham Lawton**

Graham Lawton is a staff writer at *New Scientist* and author of *Mustn't Grumble: The surprising science of everyday ailments*. You can follow him @grahamlawton

IN JUNE 2021, the government of the Seychelles decided it was time to stamp out what it had come to see as a dangerous recreational substance: balloon latex. Too many people were taking balloons to the beach and the popped remains were finding their way into the ocean to be swallowed by turtles. The government had already banned most other single-use plastic items, including straws, bags, eating utensils and cups. The balloon ban was the final warning that, in the Seychelles at least, the party is over.

The country's war on plastic was inspired in part by its stewardship of Aldabra, a large coral atoll 1120 kilometres south-west of the main island Mahé. Nobody lives there apart from a dozen or so scientists. Visitor numbers are restricted to a few hundred day trippers per year. It is a UNESCO world heritage site and a strict nature reserve. And still it has a major plastic pollution problem. "We removed thousands of tonnes of plastic from the atoll," Seychelles president Wavel Ramkalawan told the recent One Oceans Summit in Brest, France.

There was much discussion of the pervasive plastics problem at the summit, which was convened by President Emmanuel Macron of France – the world's largest ocean country by virtue of its overseas departments and regions – and attended by many world leaders. "It's a high-level summit with the presence of heads of state," said marine ecologist Enric Sala, a National Geographic explorer in residence, ahead of the meeting. And things happen at heads-of-state summits."

Things did happen. As at last year's COP26 conference in Glasgow, world leaders fell over themselves to make promises about ocean conservation and sustainable development. With both meetings, it remains to be seen whether these lofty words will translate into action. But on plastic pollution, the action has already begun. "We are now seeing growing backing for a strong, comprehensive, source-to-sea global agreement," says Inger Andersen, executive director of the United Nations Environment Programme.

The outline of such an agreement is already on the table. This month, I am packing my virtual bags for Nairobi, Kenya, to cover the United Nations Environment Assembly, the world's most powerful decision-making body on environmental action. On the agenda is a resolution to begin negotiations on a global plastic pollution treaty, which, if successful, would drastically cut manufacture and disposal of plastics and create a "booming" circular plastics economy. More than 150 countries have "expressed interest" in negotiating an agreement, says Andersen.

> **"Only a fool or a knave would deny that we have a major plastic pollution problem. But there are plenty of both"**

As Greta Thunberg would probably respond: blah, blah, blah. Agreeing a resolution to begin negotiations certainly appears to leave plenty of room for that. But John Kerry, the US special presidential envoy for climate, said in Brest that he hoped a deal would be finalised at the next round of climate talks in Egypt in November, and committed the US to get behind the negotiations.

Only a fool or a knave would deny that we have a major plastic pollution problem. Unfortunately, there are plenty of both. By November, the Republicans, whose record on the environment leaves a lot to be desired, may well be back in charge of the US Congress. Kerry acknowledged in Brest that attempts to negotiate a treaty will provoke a backlash from "powerful vested interests that push back against change, that want to ignore science even, let alone common sense", saying that "we are prisoners to some degree of the status quo".

To be fair to the plastics industry, more than 80 senior executives have said they want a treaty, according to Andersen, and there is growing recognition that rules need to be imposed. "It's clear that voluntary initiatives alone will not go far or fast enough to solve the problem," says Richard Slater, Unilever's executive director of R&D and head of the company's plastic pollution response. But at the same time, the oil and gas industry knows that making plastics from its products will keep the cash machine paying out as demand for fossil fuels dwindles. Plastic production is expected to double in the next 20 years, according to Virginijus Sinkevičius, European Commissioner for Environment, Oceans and Fisheries.

What often gets lost in the debate over plastics is that we can have the best of both worlds: ban single-use items and build a circular economy for the plastics we actually need. "Plastics are not inherently bad, it's how we use them – or rather misuse them – that causes so many problems," says Andersen. We will have to let go of frivolous, throwaway items like party balloons, but the future of plastic can still be fantastic. ■

Graham's week

What I'm reading

Otherlands: A world in the making *by Thomas Halliday, an epic tour of Earth's ancient landscapes.*

What I'm watching

This is Going To Hurt *on the BBC. Sharp as a scalpel.*

What I'm working on

I'm deep diving into ocean science at the moment.

This column appears monthly. Up next week: Annalee Newitz

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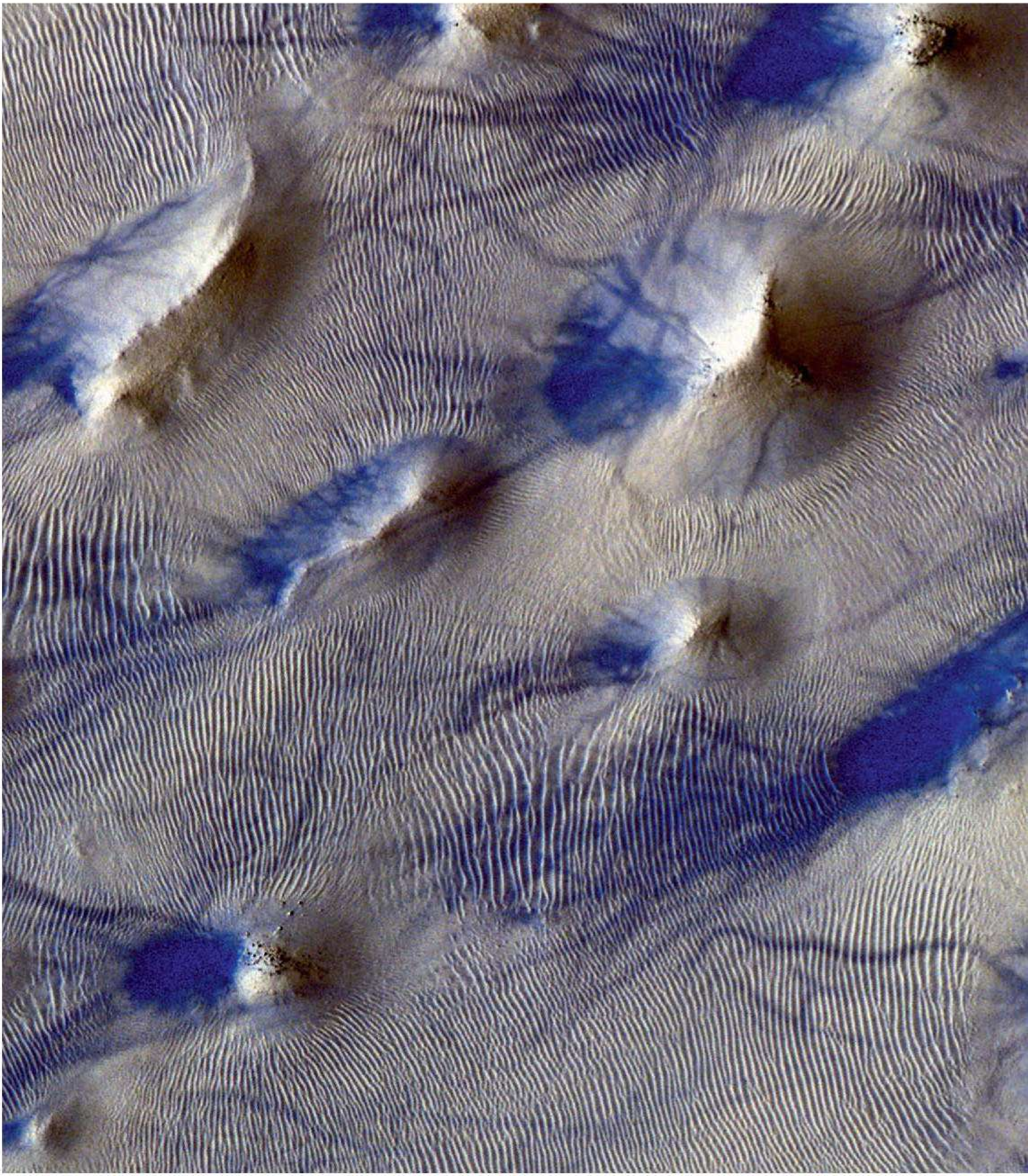
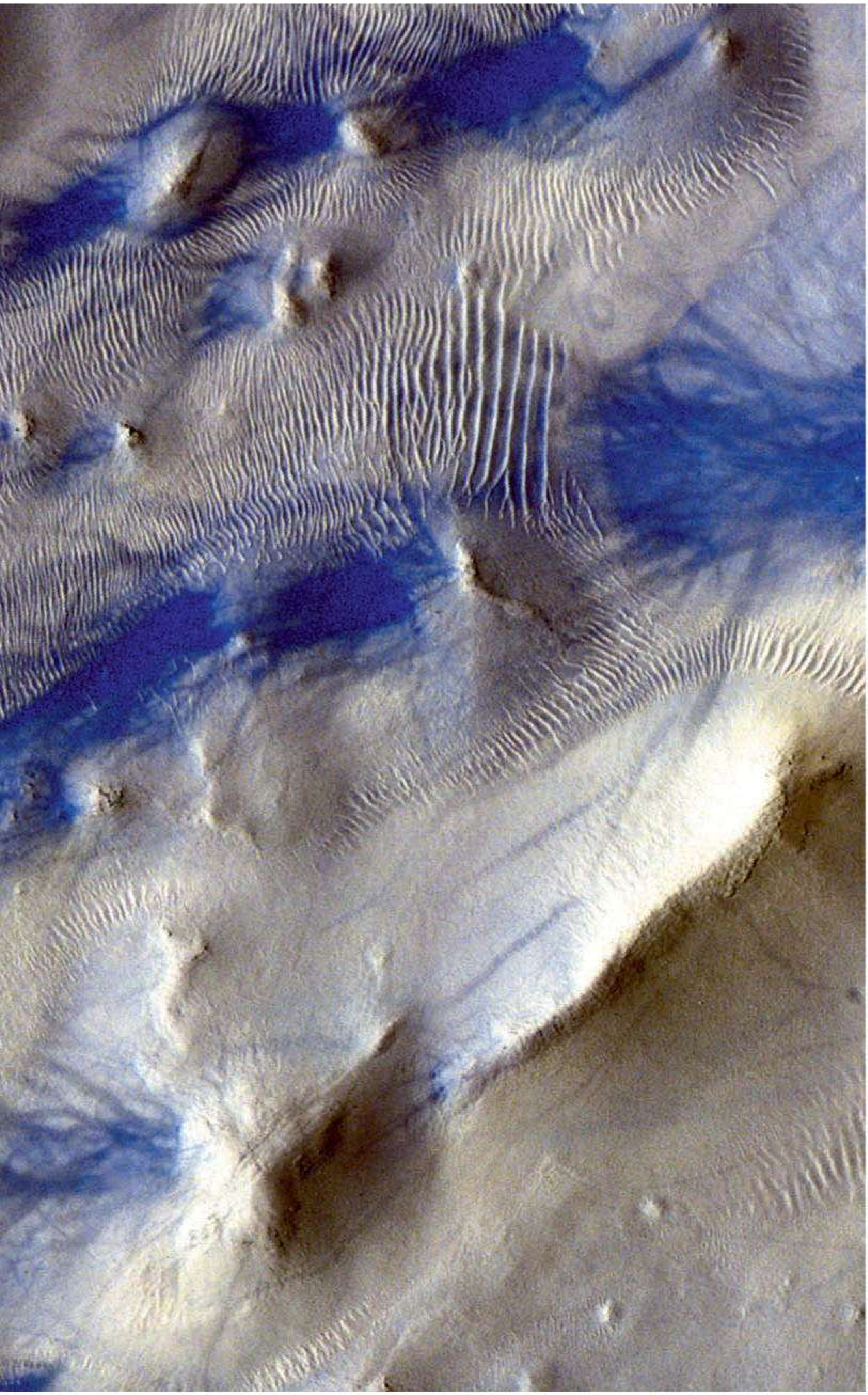




Bedevilled Mars

Photograph ESA/Roscosmos/CaSSIS

THIS intriguing landscape is one of the latest images of the surface of Mars. It was captured by the Colour and Stereo Surface Imaging System (CaSSIS) on board the ExoMars Trace Gas Orbiter (TGO). The orbiter is part of the ExoMars programme, a collaboration between the European Space Agency and Roscosmos, Russia's space agency.

This patch of terrain near the Hooke crater in Mars's southern highlands resembles "chaotic terrain" – regions of haphazardly clumped rocks seen across the planet – although it hasn't yet been classified as such.

The wispy blue threads are tracks caused by little whirlwinds known as dust devils that twist through the Red Planet's thin atmosphere. They occur when warm air rises through cooler air.

In reality, though, these tracks aren't blue. The colouring of the image appears particularly otherworldly partly because it is an infrared image, but also because multiple filters were combined to be highly sensitive to variation in the surface minerals that dust devils whip up and leave in their wake.

One of the ExoMars programme's objectives is to look for signs of past and present life on the planet. To this end, aside from snapping photos of Mars, the TGO is also searching for evidence of atmospheric gases such as methane, which can potentially indicate biological activity, and mapping water-rich regions of the planet. ▮

Gege Li

A matter of perception

The astonishing way that some people's brains interpret the world offers an insight into how we all experience reality, says **Carissa Wong**

Book

The Man Who Tasted Words: Inside the strange and startling world of our senses

Guy Leschziner

Simon & Schuster UK

VALERIA was 14 years old when she realised that most people don't see colours and feel textures when they listen to music. Now in her mid-20s, when she plays a piano, bright oranges, purples and yellows flow in and out of her sight, accompanied by fleeting feelings of warmth on her face, an ocean breeze or a sharp sensation around the spine.

Valeria has synaesthesia, a phenomenon in which stimulation of one sense generates sensations of another. People with synaesthesia can't control how their senses join up and many can't imagine living with any other form of perception.

In *The Man Who Tasted Words*, neurologist Guy Leschziner explores how the senses, and the neural circuits that underlie them, shape our view of the world. By introducing us to people with rare sensory capabilities such as Valeria, Leschziner highlights that there is no "normal" perception of reality because what we perceive as being "out there" in the world is entirely generated by activity in our brains.

The book title is inspired by James, another synaesthete, who associates words with flavours. In James's world, a trip on the London Underground is an uncontrollable buffet of flavours. Holborn station tastes of burnt matches and Liverpool Street of liver and onions.

Leschziner alludes to the fact that synaesthesia tends to run in families, but stops short of a satisfying deep dive into the research on how synaesthesia is linked to genetically determined structural changes in the brain.

As well as chronicling the experiences of people like Valeria and James, who have experienced the world in unusual ways since birth, Leschziner explores cases of sensory alteration that have affected people following illness or injury. Each case reads like a short detective story, with puzzling symptoms pieced together from Leschziner's perspective as their neurologist, supported by quotes from the individuals themselves.

We meet Alison, whose taste for trout while holidaying in Fiji led to a type of nervous system poisoning that reversed her sense of hot and cold. A sip of icy water now causes her lips to burn, while a warm shower feels freezing cold.

We encounter Nina, who lost almost all her sight after a bout of flu as a toddler caused damaging inflammation in her eyeballs. Starved of visual inputs from her eyes, her brain now hallucinates colourful shapes, cartoons and sometimes zombie faces.

> "Each case of sensory alteration reads like a detective story, with puzzling symptoms pieced together"

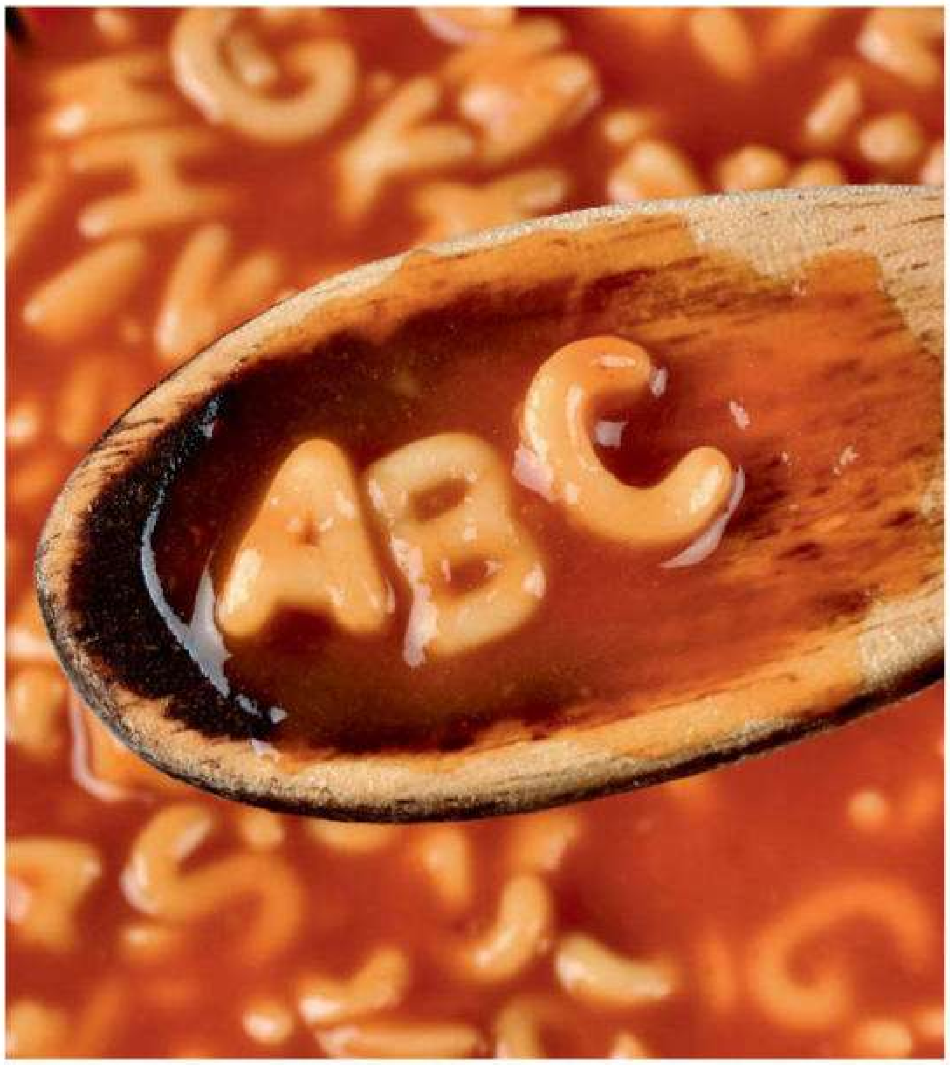
This is a condition called Charles Bonnet syndrome, which Nina finds distracting and sometimes upsetting, but is, she says, preferable to darkness.

Leschziner also meets Paul, who can't feel pain due to a genetic mutation that affects his sensory nerves. He has had a lifetime of injuries caused by a low aversion to danger because he can't feel the painful consequences of risky behaviour. This has led to so many bone and joint problems that his movement is restricted. Leschziner explores the emotional toll of the condition on Paul and his parents, who lost a 13-month-old daughter with the same condition after her sepsis went undetected because she wasn't showing signs of distress.

This book is packed with examples of remarkable perception, but it doesn't stop there. Leschziner also considers how our senses affect the way we all live our lives. Smell, for example, plays a role in our choice of partners in ways that have driven the evolution of our species. He also touches on more philosophical questions, such as how we know what the world is really like, given that we can't say with any certainty that our experience of it is anything like that of other people.

Throughout the book, Leschziner makes it clear that every person's reality is as valid as the next. There are, however, moments where he seemingly assumes that the reader experiences all five senses – and in the "normal" way. At other points, there is unnecessary repetition, which detracts from the message he is trying to get across.

Overall, though, Leschziner provides a thought-provoking journey through the fundamental role our senses play in our experience of life and punctures the illusion that our window on the world is the unflinching truth. The fact that it is anything but only makes it more magical. ▮



SHUTTERSTOCK/BRIAN MUELLER

Tasting words is one possible outcome of crossed sensory wires in the brain

Double or quits

The downsides of cloning turn out to be less amusing than this genre-defying film intended, says **Davide Abbatescianni**

Film

Dual

Riley Stearns

Coming in 2022

COURTESY OF SUNDANCE INSTITUTE

Preparing for a death match against your double brings mental and physical challenges

FROM its very first scene, *Dual* throws us into a highly disturbing world. The film, which premiered at this year's Sundance Film Festival, opens with a man standing on a football pitch in front of an array of weapons. While he hesitates over which one to pick, his opponent takes the opportunity to shoot. It soon transpires that the attacker is a clone of his victim, and that the pair are locked in a fight to the death that is being televised for a bloodthirsty audience.

This intriguing opening scene precedes the introduction of *Dual*'s lead character, a young woman called Sarah (Karen Gillan). We learn that she has a penchant for porn and booze, and has somewhat unhealthy relationships with her boyfriend and mother. Then she is hospitalised with severe gastrointestinal bleeding and discovers that she is terminally ill. To soften the blow, her doctor offers her the option of a "replacement", a hastily produced yet physically perfect genetic copy, which she can train to slot into her life after she is gone. The main selling point is that it will save her loved ones from the pain of losing her. Struggling to process the news, Sarah signs up and sets about training her replacement to take over her life.

But here is the twist: 10 months later, Sarah is still alive and her condition is no longer terminal. Yet her double has replaced her so successfully that even her estranged boyfriend and mother prefer the copy to the original. At this highly improbable point in the story, *Dual*'s narrative coherence begins to fall apart.

In the film, the laws surrounding cloning state that there can only be one living version of each person. If the original Sarah isn't dying, then one of them must die. Sarah assumes this will be the copy, but her loved ones disagree. They cut her out of their lives and start a legal procedure to protect her double.

The law also states that such matters can only be settled via a fight to the death. Oddly, it seems that Sarah wasn't aware of this risk at the outset, despite these sorts of fights being regularly broadcast on TV. Stranger still, Sarah doesn't seem to hold a grudge against her boyfriend, meeting him for lunch even after he has sentenced her to a death match.

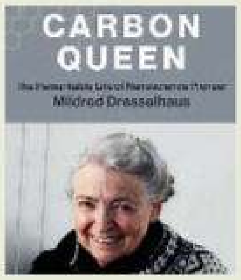
Things get even weirder when she starts training with a bizarre combat instructor called Trent (Aaron Paul, best known as *Breaking Bad*'s Jesse Pinkman). He tasks her with visiting an autopsy and shows her pictures of mutilated bodies to get her used to the sight of gore. Training also involves hip-hop dancing and a bizarre scene where they practice fighting in slow motion.

***Dual* is meant to be a dark, deadpan comedy, but it doesn't quite hit the mark. The realistic violence shown throughout just isn't funny, and the eerie score and atmosphere make the film feel more like a thriller. Yet it doesn't fit well into that genre either. Events unfold in too surreal and nonsensical a fashion to maintain an acceptable level of credibility. The ending feels like a psychological drama, but one that is far too predictable. The lack of stylistic focus is reflected in the actors' performances, which shift between a puzzling apathy and perplexing moments of overacting.**

It seems that director Riley Stearns aims to satirise the society we live in, where people repress their feelings and enjoy the spectacle of violence. Yet this message is delivered clumsily and doesn't make up for the frustrating viewing experience. All in all, *Dual* feels like a missed opportunity. Establishing clearer rules for this dystopian world – and sticking to them – would have significantly improved the quality of this effort and done justice to what, on the face of it, is an appealing premise. ▮

Davide Abbatescianni is a writer based in Cork, Ireland

Don't miss

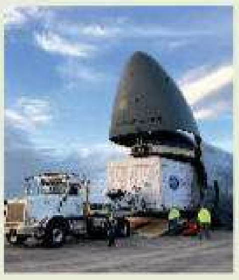


Read

Carbon Queen is Maia Weinstock's account of the remarkable life of nanoscience pioneer Mildred Dresselhaus, who, from the 1950s, defied society's expectations of women to become an influential scientist and engineer.

Visit

Two Heads delves into how our brains work with other brains. Join renowned husband-and-wife researchers Uta and Chris Frith as they explore the real-life implications of social neuroscience. At 7pm GMT on 1 March at the Royal Institution, London.



Watch

GOES-T launch provides the chance to (virtually) be in the room as NASA and NOAA's latest, and most advanced, weather and environmental satellite blasts off into space at 9.38pm GMT on 1 March. Register online.

NASA/GREGORY B HARLAND; TWO HEADS ART BY DANIEL LOCKE

Work-life balance?

What if you could forget work when you leave the office and leave home troubles behind when you return? It may not end well, finds **Bethan Ackerley**

ATSUSHI NISHIJIMA/APPLE TV+

Mark Scout, played by Adam Scott, works for a shadowy corporation

TV

Severance

Ben Stiller and Aoife McArdle

Apple TV+

THE first thing you should know about Mark Scout is that he is an employee of Lumon Industries, the nebulous corporation at the heart of new sci-fi thriller series *Severance* from Apple TV+. He is many other things besides – a cynic, a widower, a former history professor – but it is this fact that has come to define him, right down to his very biology.

That is because Mark (Adam Scott) is one of a select few who have chosen to undergo severance, an irreversible brain surgery that causes their memories of their jobs to be divided from the rest of their life. While working in Lumon's macrodata refinement department, Mark's "innie" has no knowledge of who he is outside the office. Likewise, his "outtie" can't recall how he is treated at Lumon or the nature of the work he performs.

Why sever your job from your personal life? Lumon pitches the procedure as a means of creating a healthy work-life balance. When you head out of the door at 5pm, you really are switching off until tomorrow. For some, there are other benefits: severance means Mark can briefly forget about his wife's death and hold down a job despite his still-debilitating grief. The severed workers made their decisions willingly, but there are few ways out once the process is complete.

Mercifully, *Severance* contains no explicit allusions to the pandemic's effect on our relationship with work, despite the series being filmed in 2020 and 2021. It largely steers away from implausible explanations of how severance is achieved, something that requires suspension of disbelief for anyone with a basic knowledge of how memory works.

Instead, the series is an indictment of what the working world has long been for many: a slow, degrading assault on the soul. Mark's job is dull, requiring him to sort data packets into folders according to unknown, seemingly arbitrary criteria. He is assured without evidence that his work is of vital importance, and his weak incentives are the promise of a desk toy or a waffle party at the end of the quarter.

Sound familiar? The life of a macrodata refiner is only a few degrees removed from so many jobs. Even the devil's bargain of severance is just an extreme version of what many employees already do: leave your personal life at the door, do what you are told and, above all, be grateful.

> **"*Severance* is an indictment of what work has become for many: a degrading assault on the soul"**

It takes the arrival of a new recruit after the sudden disappearance of his colleague Petey (Yul Vazquez) for Mark to start to question this arrangement. Like all severed workers, Helly (Britt Lower) wakes up on a boardroom table and is unable to even remember her name. Her fervent requests to leave are finally granted, only for Helly's outer self to inexplicably return to Lumon each day, putting her in the confusing position of being both prisoner and jailer. "Every time you find yourself here, it's because you chose to come back," Mark reminds her.

Soon, Helly's defiance rubs off on work-based Mark, while in the outside world he is contacted by Petey, who has reconnected to both sides of his memories at a grave cost to his health. Unbeknownst to each other, the two versions of Mark start to question what Lumon really does.

Severance is a compelling thriller, with a look and feel straight out of a Stanley Kubrick film. Even the most casual Kubrick fan will notice the homages to his style, from the clinical basement where severed workers spend their days to the unnerving stare of Mr Milchick (Tramell Tillman), the department overseer. The Lumon office even sits on the edge of a snowy, isolated town, haunting the residents like a corporate version of the Overlook Hotel from *The Shining*.

Despite borrowing from such illustrious influences, *Severance* is a rare beast in that its premise is original. In a viewing landscape increasingly dominated by sequels and remakes, it is a unique concept that provides a genuine commentary on the all-encompassing role of work in our lives. The perspective it offers is disturbing – and will keep you coming back each week, even if, like Mark and his colleagues, you aren't exactly sure why. ▮

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SATURDAY 12 MARCH

TURING STAGE

10:30 - 11:30

TOWARDS A RATIONAL LIFE: HOW THINKING SCIENTIFICALLY CAN HELP NAVIGATE TODAY'S WORLD

Jim Al-Khalili, Professor of Theoretical Physics, University of Surrey

12:10 - 13:10

DNA FAMILY SECRETS

Turi King, Professor of Genetics, University of Leicester

14:00 - 15:00

THE GEOLOGICAL RECORD OF CLIMATE CHANGE

Christopher Jackson, Chair in Sustainable Geoscience, University of Manchester

15:45 - 16:45

WHY CALORIES DON'T COUNT

Giles Yeo, Principal Research Associate, University of Cambridge

JOULE STAGE

10:45 - 11:25

MUON PHYSICS: HAVE WE FOUND A NEW FORCE OF NATURE?

Alex Keshavarzi, Particle Physicist, University of Manchester

11:50 - 12:30

THE EXPECTATION EFFECT: HOW YOUR MINDSET SHAPES YOUR HEALTH, HAPPINESS, AND LONGEVITY

David Robson, Science writer and author

13:15 - 13:55

BE EXTRAORDINARY: 7 KEY TOOLS TO TACKLE STRESS & FEAR

Jennifer Wild, Associate Professor & Consultant Clinical Psychologist, University of Oxford

14:20 - 15:00

FUTURE AIR POLLUTION: PLASTIC DUST AND THE POTENTIAL TO IMPACT HEALTH

Stephanie Wright, Lecturer in Environmental Toxicology, Imperial College London

15:30 - 16:10

RACE TO THE BOTTOM: HOW HUMANITY IS EXPLORING THE DEEP OCEAN

Jon Copley, Associate Professor of Ocean Exploration, University of Southampton

BIRD STAGE

11:00 - 11:40

THE QUEST FOR LIFE'S ORIGIN

Michael Marshall, Freelance science writer

12:10 - 12:50

UP IN FLAMES: UNDERSTANDING THE RISK OF URBAN FIRE

David Rush, Senior Lecturer in Structural Engineering, University of Edinburgh

13:25 - 14:05

JOURNEY TO THE SOLAR SYSTEM'S ICE GIANTS

Leigh Fletcher, Associate Professor in Planetary Science, University of Leicester

14:40 - 15:20

WHAT'S EATING MEN? THE BATTLE FOR MALE MENTAL HEALTH

Fraser Smith, Counselling Psychologist, Psychology Scotland & GetPsyched

15:50 - 16:30

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SUNDAY
13 MARCH

TURING STAGE

10:30 - 11:30

CLIMATE CHANGE: HOW WE CAN TAKE ON THE FIGHT AND SAVE THE PLANET

Mark Maslin, Professor,
University College London

12:10 - 13:10

HOW TO GROW A SUPERMASSIVE BLACK HOLE

Rebecca Smethurst, Astrophysicist,
University of Oxford

14:00 - 15:00

YOUR SECRET BODY

Daniel Davis, Professor of Immunology,
University of Manchester

15:30 - 16:30

HOW TO LEAVE THE PLANET: A ROUGH GUIDE TO SPACE TRAVEL

Dallas Campbell, Television presenter & author
Suzie Imber, University of Leicester

JOULE STAGE

10:45 - 11:25

TUNING IN TO THE INVISIBLE UNIVERSE

Philippa Hartley, Postdoctoral Fellow,
SKA Observatory

11:50 - 12:30

THE HIDDEN SECRETS OF HOW TO SURVIVE AN ECOLOGICAL CATASTROPHE

Penny Spikins, Professor, University of York

13:15 - 13:55

AI: FRIEND OR FOE?

Beth Singler, Junior Research Fellow
in AI, Cambridge University

14:20 - 15:00

ONE ATOM THIN MATERIALS AND MINUTE VOIDS

Radha Boya, Chair in Nanoscience,
University of Manchester

15:45 - 16:25

DO YOU REALLY WANT TO KNOW? THE RISKS OF PERSONAL GENETIC TESTING

Emma Yhnell, Lecturer, School of
Biosciences, Cardiff University

BIRD STAGE

11:00 - 11:40

THE SOCIAL INSTINCT: HOW COOPERATION SHAPED THE WORLD

Nichola Raihani, Professor of
Evolution & Behaviour, UCL

12:10 - 12:50

WHY DO PEOPLE BELIEVE CONSPIRACY THEORIES?

Daniel Jolley, Senior Lecturer,
Northumbria University

13:25 - 14:05

ANTIBIOTICS IN CRISIS: CAN WE STEM THE SPREAD OF BACTERIAL RESISTANCE?

Kip Heath, Deputy Lead Healthcare
Scientist, Great Ormond Street Hospital

14:40 - 15:20

NANO: THE SPECTACULAR SCIENCE OF THE VERY (VERY) SMALL

Jess Wade, Research Fellow, Imperial College
Roma Agrawal, Structural Engineer and Author

15:50 - 16:30

MILLION DOLLAR PUZZLES: THE SIX BIGGEST UNSOLVED PROBLEMS IN MATHS

Tom Crawford, Teaching and Outreach
Fellow, University of Oxford

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HAVE A GO

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GET LOST IN SPACE

For all the wannabe astronauts, you can come and smell space at the New Scientist Discovery Tours stand or experience an immersive documentary on the Apollo program in the pop-up planetarium.

STICKY SCIENCE

If you like the stickier side of science, don't miss the UK Health Security Agency's "Snot gun", where you can experience big sneezes and super slimy snot.

LIFE SAVING TECH

Alzheimer's Research UK will be bringing wearable technology to New Scientist Live to demonstrate the latest advances in tech for the early detection of dementia.

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Editor's pick

Poor products run rings round circular economy

12 February, p 38

From Carole Allsop and Tony Kaleda, London, UK

By coincidence, just after reading your article on the circular economy, our blender (only a few years old) stopped working. After attempts to repair it using YouTube videos, we have had to give up. It, like so many modern appliances, suffers from built-in obsolescence. To buy a new spice and nut grinder, we decided to google "sustainable and repairable kitchen equipment", without much success. Isn't it time this aspect became a fundamental part of reviewing products of this kind and isn't there also a huge hole in the market for a producer of equipment that meets such criteria?

From Steve Blyth, Roade, Northamptonshire, UK

I have a suggestion in response to your interesting article on the circular economy, "Waste not… want not?". There should be mandatory return of used items and packaging from end users via their suppliers to manufacturers. This could utilise delivery vehicle fleets on return trips, encourage design for disassembly and reuse (fostering the latter), reduce excess packaging and minimise waste-processing activities.

Green heating is about saving Earth, not cash

12 February, p 12

From Rachael Padman, Cambridge, UK

Amid worries about energy price hikes, it is naive for anyone to think that the shift away from gas boilers to electrically powered heat pumps is going to save householders money on energy in the short or even medium term. Energy prices in the UK are set in a way that means that if you have to pay high prices for even a small amount of gas-fired electricity, you pay them for all your electricity.

The reason for the shift to heat pumps isn't to save money – it is to save the planet. We shouldn't pretend it is going to be cheap: high per-unit costs now are the price for our earlier neglect.

From Mike Clarke, Castle Hedingham, Essex, UK

You report that some MPs are pushing hard to bring forward the ban on new gas boilers in England to speed up their replacement with air-source heat pumps and other systems within a couple of years. For these heat pumps, efficiency drops as the temperature falls and so the electricity demand rises. The electricity grid and local wiring may not be able to support this demand without upgrading.

Megabats have some pretty mega differences

5 February, p 25

From Talia Morris, Cape Tribulation, Queensland, Australia

You report on a study on the two major groups of bats that claims the only significant difference between Yinpterochiroptera and Yangochiroptera is a single ear bone. However, the megabats, or Pteropodidae, have completely different brain structures and visual systems to both the rest of the Yinpterochiroptera and all of the Yangochiroptera.

Mass extinctions may also mark the Anthropocene

29 January, p 14

From William Hughes-Games, Waipara, New Zealand

Amid debate about the location with the best record of the start of the Anthropocene epoch, it could be argued that it started in Australia some 50,000 years ago, in America 12,000 years ago and in New Zealand 700 years ago, when the first people arrived. In a geological blink of an eye, most of the megafauna disappeared.

Birds double down on breeding in good times

15 January, p 25

From Veronica Szery, Wolumla, New South Wales, Australia

Further to the observation of fairy wrens breeding out of season in Western Australia in recent years, since drought ended in Australia in 2021, we have had some of the wettest years for a while. It isn't uncommon for native species to bring up two batches of babies in a good season, when conditions are favourable.

Wildlife doesn't consult the calendar, then act accordingly. Animals do a weather check. If the season looks good, they will go for bust to bring up another brood.

Perhaps classical space doesn't always commute

5 February, p 38

From Paul Hield, Bristol, UK

I had to chuckle while reading the section "Does space-time commute?" in your feature on quantum reality. The example for classical space being commutative is that it doesn't matter if you travel 5 kilometres south and then 3 kilometres west or vice versa, you end up in the same place. But, of course, that falls apart when you are near a pole and is only approximately true elsewhere, although the error quickly becomes very small the further from a pole you are. In a sense, this makes the point perfectly: what we hold to be self-evident in fact doesn't work under extreme conditions, with proximity to a pole or at the very small scales of the quantum world.

Migraine can be enough to make you vomit

29 January, p 38

From James Bailey, Southampton, UK

For me, migraine involved a lot of nausea. There were times when I was actually sick. I discovered after some years that taking a travel sickness pill greatly reduced the nausea and made the headache symptoms more bearable.

Birds could have beaten chimps to insect medicine

12 February, p 10

From Erik Foxcroft, St Albans, Hertfordshire, UK

You report that chimpanzees may be the first animals seen to apply insects to wounds, but there are a number of bird species that use ants to treat skin parasite infestations, exploiting the formic acid from their stings.

Does icy moon also have a secret atmosphere?

22 January, p 18

From Stephan Győry, Sydney, Australia

Your article says an ocean may be hiding under the ice on Saturn's small moon Mimas. Given the suggestion that water is sloshing around under the ice, is it possible there is a layer of gas between the ice and the liquid? If the minerals beneath were releasing gas, then perhaps it couldn't get through the ice, making a thin atmosphere. ▮

For the record

- ▮ **The International Garden Photographer of the Year competition (12 February, p 30) is organised by IGPOTY.**
- ▮ **Quick quiz (12 February, p 55): Titan, which is the second largest moon in solar system, orbits Saturn.**

Want to get in touch?

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Long-haul fight

As normal life resumes for many people, millions of others are still battling long covid. At last the condition is finally getting the attention – and potentially treatments – it so desperately needs, finds **Michael Marshall**

PETE REYNOLDS

LAUREN NICHOLS first fell ill on 10 March 2020. Her symptoms started with crushing fatigue, swiftly followed by headaches, brain fog and agonising gastrointestinal pain. “My oesophagus was incredibly painful,” she says. “Every time I took a breath of air, every time I spoke, I wanted to die.” Her doctor diagnosed bad acid reflux.

Nichols had an inkling it was covid-19, and later tested positive, but her symptoms didn’t run their course in a couple of weeks, as official advice at the time stated. Two years down the line, she is still waiting for relief.

She isn’t alone. Alongside the 5.8 million people confirmed to have died from the coronavirus, tens of millions more have long covid: a lingering condition with symptoms that last for months or years. These “long haulers” are still experiencing the ill effects of infection, often with little help from doctors. “They still aren’t listening to patients,” says Nichols, who is now vice president of Body Politic, an international advocacy group currently focusing on covid-19.

Despite a lack of funding and attention from governments, two years into the pandemic, long covid is beginning to reveal its secrets. “Scientists are working around the clock to try to understand what’s going on,” says Akiko Iwasaki at Yale University. Not only are we starting to appreciate why some people remain ill after infection while others are left with barely a sniffle, we are making sense of what is happening in the body – and with that, the ways to treat and even prevent it.

The first whispers of a lingering condition associated with covid-19 started within months of the disease emerging. Some people who had been infected with SARS-CoV-2 reported that they couldn’t get better. The multitude of symptoms varied from person to person and changed over time in unpredictable ways.

“MY OESOPHAGUS WAS INCREDIBLY PAINFUL. EVERY TIME I TOOK A BREATH OF AIR, EVERY TIME I SPOKE, I WANTED TO DIE”

The term “long covid” was coined by archaeologist Elisa Perego in a tweet in May 2020 and was swiftly adopted by the world. What has taken much longer to agree on is a definition of what it is; how many people have it; why some get it while others don’t; and how to treat it. Today, with better definitions of the condition and a host of published papers, scientists can start to provide some answers. We now know that around 1.3 million people in the UK currently have long covid, as reported by the Office for National Statistics on 3 February. That number is likely to grow following a wave of infections with the omicron variant, which recently swept through the UK’s largely unvaccinated young people.

The global toll is estimated to be around 100 million, according to prevalence data from a meta-analysis published in December 2021 of 81 studies, which found that 32 per cent of people diagnosed with covid-19 were still experiencing fatigue 12 weeks later, while 22 per cent had cognitive impairments.

We also know that certain people are more at risk. A study published in January showed that people were more likely to develop long covid if they had type 2 diabetes; if they had certain “autoantibodies” that can attack their own tissues; if pieces of the virus’s genome were still circulating in their blood; and if they had previously been infected with the Epstein-Barr virus, which causes glandular fever. Recently, we have also discovered that people with long covid have a distinct set of bacteria in their guts, although it isn’t clear whether their gut bacteria predisposed them to the illness, or the illness triggered the change in gut bacteria.

Of over 200 known symptoms associated with long covid, the most common are shortness of breath, post-exertional malaise – in which even a tiny amount of exercise leads to exhaustion – and cognitive difficulties dubbed brain fog.

This last symptom is remarkably common, arising even in people who don’t think they have long covid. In a study published in January, Sijia Zhao at the University of Oxford and her colleagues gave cognitive tests to 53 people who didn’t report lasting symptoms after covid-19 infection, › alongside 83 controls who reported not having been infected. The covid-19 group mostly matched the controls, but were worse at remembering pictures they had seen and at focusing on a task. Fortunately, these difficulties eased. "There is a slow but quite obvious recovery from these deficits after about six to nine months," says Zhao.

Others aren't so fortunate. Nichols is still unwell, having experienced a roller coaster of symptoms including severe diarrhoea, an "utterly terrifying" mini-stroke, shingles and hair loss. Her case is severe, but not uniquely so. "A lot of us are just consistently not well, or getting worse," she says.

Long covid isn't unique in this respect. Many other viruses, such as those that cause Zika or pneumonia, can cause long-term symptoms. Chikungunya virus, which is common in the tropics, causes fever, but is often followed by lingering symptoms that resemble arthritis.

Given the variety of long covid symptoms, finding one mechanism behind it or a single treatment is unlikely. "I would caution anybody who tells you they have one answer to long covid," says Mark Toshner at the University of Cambridge. He says we probably aren't dealing with a single disease pathway. Instead, we are getting a number of overlapping answers, some of which describe mechanisms we already knew about from other viruses, some of which may be heightened in covid-19 and some of which may be specific to it.

Promising paths

As research progresses, a long list of possible mechanisms is slowly being cut down to the most promising candidates. These include the idea that the virus may cause severe tissue damage that the body can't repair. This is particularly likely in people who require intensive care, says Iwasaki. Other possible explanations suggest the virus may leave the immune system permanently disrupted, or even trigger an autoimmune disease in which the immune system attacks healthy tissue. In some cases, the virus may linger in the body, causing ever more harm.

The idea that SARS-CoV-2 might stick around in the body was initially rejected by many experts because the virus stopped showing up in blood tests within weeks of infection. It was a mistake to dismiss the idea, says Michael VanElzakker at Massachusetts General Hospital in Boston. He says the problem was that it was easier to identify abnormal immune cell activity from a blood test than to identify fragments of virus that may be hiding out anywhere in the body.

In January 2021, a key study published by Michel Nussenzweig at the Rockefeller University in New York and his colleagues reignited the idea. They showed that memory B-cells, part of the immune system, become increasingly attuned to the virus between 1.3 and 6.2 months after infection – suggesting that the virus was still present, and that B-cells were adapting to it, well after it stopped showing up in blood tests.

Then, in December, Daniel Chertow at the National Institutes of Health in Bethesda, Maryland, and his team reported in a preprint, a study yet to be peer reviewed, that the virus was "widely distributed" around the bodies and brains of 44 covid-19 patients who had died. "It's evidence that the virus is sticking around for months and months," says VanElzakker. An earlier study supported this finding by showing the virus lingering in people's guts.

The implication is simple. Many people with long covid may still have SARS-CoV-2 in their bodies, and a crucial step in helping them recover will be to destroy the virus. Monoclonal antibodies would be worth trying,

"WE WILL THROW THE FULL IMMUNOLOGIST TOOLKIT AT THEM TO WORK OUT WHAT HAS HAPPENED"

A 3D scan shows damage to the lung from covid-19

SAMUNELLA/ALAMY

says Iwasaki. Vaccination could also help. A review published this month by the UK Health Security Agency showed that it helps cut the risk of developing long covid, over and above helping you avoid infection in the first place.

It also showed that some unvaccinated people with long covid who were subsequently vaccinated had reduced symptoms. One theory is that the vaccination may help clear lingering fragments of the virus from the body.

However, it is crucial to differentiate between long haulers who are still fighting the virus and those whose illness is caused by their own immune system. The evidence for immune disruptions in long covid is overwhelming. Many studies show that immune chemicals are overproduced in long covid. These have widespread knock-on effects, including disrupting brain chemicals.

This chemical chaos might explain long covid brain fog, if Iwasaki's experiments are anything to go by. In one, mice infected with SARS-CoV-2 had elevated levels of an immune chemical called CCL11, which was also found in long covid patients with cognitive symptoms, but not in those with long covid and no cognitive symptoms. In the mice, brain cells called microglia were also inflamed. We know from studies of "chemo brain", the brain fog that sometimes follows chemotherapy, that inflamed microglia can damage neurons, causing cognitive disturbances. The suggestion is that long covid brain fog may be caused by inflammation of the microglia.

To get a clearer picture of which immune system alterations pertain to which long covid symptoms, Danny Altmann at Imperial College London and his team are now grouping people with long covid by their symptoms, with, he says, the intention of "throwing the full molecular immunologist toolkit at them", to pick apart what has happened to their bodies.

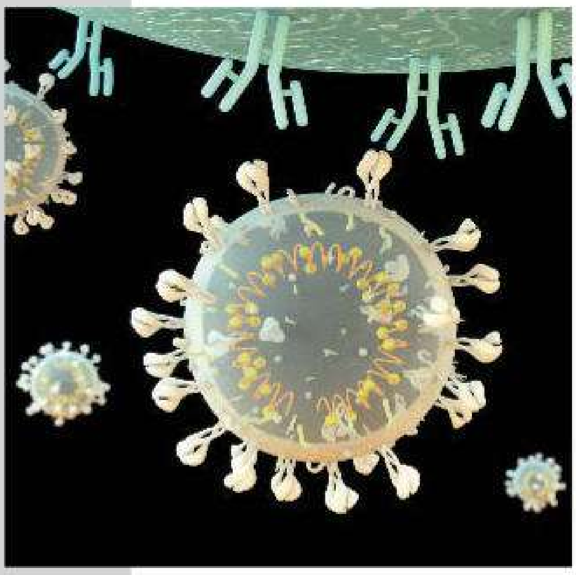
Blood vessels might also be involved, an idea that has grabbed the imaginations of many long haulers. This is the notion that the primary cause of long covid is tiny blood clots, which restrict the flow of blood to the organs and damage the walls of blood vessels. Such is the enthusiasm for this idea that #TeamClots has become a popular hashtag on Twitter.

The hypothesis is the brainchild of researchers co-led by Resia Pretorius at Stellenbosch University in South Africa. She has previously argued that bacteria in blood can disrupt clotting, which occurs to stop bleeding, and that this malign clotting plays a role in many conditions, including Alzheimer's. Could the same be true for a virus?

In early 2021, Pretorius started collecting

TREATMENT TRIALS

With a lack of official treatments, some people with long covid symptoms are turning to clinical trials and do-it-yourself therapies, says **MB Caschetta**



ANATOMIC GROOVE/SCIENCE PHOTO LIBRARY

Illustration of a a B-cell binding to SARS-CoV-2 in an immune response

On Body Politic's covid-19 support group, which uses the app Slack, my username says it all. I am MBCaschetta_May2020. I caught covid-19 on 15 May 2020 and I have been battling long-term symptoms ever since: lung pain, muscle weakness, brain fog, debilitating exhaustion and a perpetually sore throat.

Despite the promise of new treatments (see main story), for those who have been suffering for years, interventions still feel far away.

So, what is a long hauler to do? All around the world, desperados like me are entering research trials of treatments that have proven efficacious in other diseases whose symptoms resemble those of long covid.

I have enrolled in a clinical trial at the University of Massachusetts Amherst, where I will strap on a pair of scuba diver-like trousers with pockets that will circulate warm water around my lower extremities. My heat therapy will take 40 minutes, five days a week, for eight weeks. The team will look out for improvements in a battery of chemical markers measured at the start of the trial.

The trial's coordinator, Corinna Serviente, says that heat therapy has improved muscle function and the health of blood vessels in other conditions and in healthy people, and may also work to relieve muscle aches and fatigue in long covid. So far, only two people, both in their 70s, have participated. It is too soon to tell whether their markers suggest any improvement, or if they feel any better.

There are many other trials targeting the multitude of symptoms associated with long covid. For instance, researchers at the University of California, San Diego, are investigating hyperbaric oxygen therapy, in which you breathe pure oxygen in a pressurised environment. Under these conditions, the lungs gather more oxygen than normal, which is thought to promote healing, decrease inflammation and encourage better oxygen supply after the therapy is completed. The team hopes it may improve people's shortness of breath or difficulties exercising.

Meanwhile, investigators at Hackensack University Medical Center in New Jersey are planning to test beta blockers on long haulers. These drugs reduce blood pressure and ease stress on the heart and are used off-label to treat irregular heart rhythms – something many people with long covid also experience.

And at Missouri State University in Springfield, sodium pyruvate – a non-steroid nasal spray that has shown promise in lung disease, improving lung function and reducing coughing and fatigue – is being tested on a group of people with long covid. The list goes on.

Will these interventions work? Only time will tell. But like many other long haulers, I am willing to try anything. So, I find myself googling "hyperbaric oxygen therapy near me". I talk to my family doctor about prescribing low-dose naltrexone, an off-label drug for chronic fatigue syndrome, after seeing it being tested in trials for long covid. I look up nitric oxide that bodybuilders take to improve blood oxygen levels in their muscles and wonder whether I should talk to my doctor about that next.

In my own desperate cohort at home – sample size of one – I really need something to work.

MB Caschetta is a writer based in Massachusetts

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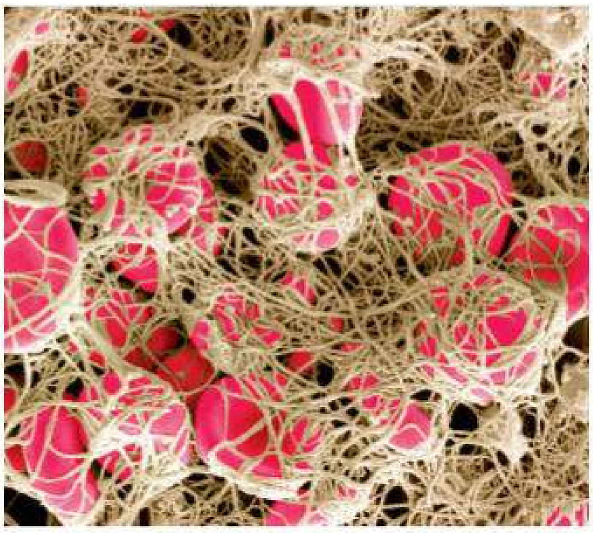

STEVE GSCHMEISSNER/SCIENCE PHOTO LIBRARY

Abnormal blood clots may be one cause of long covid

blood samples from long covid patients. She focused on the plasma, the liquid part in which red and white blood cells are carried. Under the microscope, she saw lots of what she calls "microclots": tiny lumps of material resembling blood clots. The microclots were unusually difficult to break down, compared with normal clots. They didn't show up in the blood of people who had never been infected with SARS-CoV-2.

In a second study, Pretorius's team showed that the spike protein from the virus can, on its own, disrupt the normal clotting process. Clots form when a protein called fibrinogen is converted into a second protein called fibrin. The researchers discovered that the spike protein altered the three-dimensional structure of the fibrinogen – a finding that has since been backed up by other work.

It is unlikely that the spike protein used in covid-19 vaccines would have the same effect because the volume given is too small and localised to generate a significant interaction with fibrinogen circulating in the blood, says Robert Ariëns at the University of Leeds, UK.

The Pretorius group's most dramatic discovery comes from a preprint published in late December 2021. The researchers examined the blood of 70 people with long covid and found microclots in all participants. Then they gave 24 of them three medications to stop clots from either forming or being maintained. Two were antiplatelet agents – clopidogrel and aspirin – and the third was an anticoagulant called apixaban. Afterwards, the number of microclots fell. According to the 24 recipients of the drugs, their main symptoms – shortness of breath, fatigue and brain fog – were relieved.

There was no control group, so the findings are preliminary, but it could be that the clots are interfering with oxygen delivery, leading to these symptoms. The idea was backed up by another preprint last month. Fergus Gleeson at the University of Oxford and his colleagues pumped the noble gas xenon into the lungs of 11 people with long covid who were never hospitalised, 12 people who were hospitalised with covid-19 but didn't have long covid, and 13 people without covid-19. The xenon made it into the lungs, but struggled to cross into blood vessels and then into red blood cells in those with long covid.

Cardiovascular specialists say the microclot hypothesis is intriguing but unproven. "It is possible that this is something really interesting going on here, but the evidence as yet makes me cautious," says Ariëns. He points out that the microclots have only been seen by the Pretorius group. "I'd like to see it confirmed in other labs." Pretorius and her group are currently applying for a full clinical trial to test their triple therapy in more patients. "We need that desperately," she says.

A resolution to the microclot debate may be months away, but meanwhile, millions of people still experiencing long-term symptoms from covid-19 infection are desperate for treatments and many are willing to try anything (see "Treatment trials", page 41).

> **"I'D BE SURPRISED IF WE DIDN'T HAVE SOME PRETTY GOOD ANSWERS AND A SHELF OF THERAPEUTICS A YEAR FROM NOW"**

Global effort

For Toshner, the solution is to emulate the international RECOVERY trial, which offered experimental treatments to people hospitalised with acute covid-19 and led to key discoveries, including the usefulness of dexamethasone, a steroid that significantly reduces death in people with severe covid-19. "Right now, all around the world, long covid clinics are being set up," he says. He wants everyone who attends to be invited to take part in randomised trials of potential therapies. That will give participants the opportunity to try things under the supervision of a doctor, and at the same time create large sample sizes and robust results. "There needs to be international collaboration," he says.

There is one more path that holds promise – a medicine that can stop people getting long covid in the first place. Two strong candidates for this are apixaban, the anticoagulant used in Pretorius's trial, and atorvastatin, an anti-inflammatory that could help dampen an overactive immune system. To test these drugs, Toshner and his colleagues have set up a clinical trial called HEAL-COVID that will send hospitalised patients home with these extra medications, in the hope of preventing long-term complications. Early results may be available within the year.

Altmann says he is optimistic that there is light at the end of the long-hauler tunnel. "I'd be surprised if we didn't have some pretty good answers and a shelf of therapeutics a year from now." ▮

This article isn't intended as medical advice. If you are experiencing long covid symptoms, you should seek help from your family doctor.

Michael Marshall is a science writer and author of *The Genesis Quest. He is based in Devon, UK*

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THE HIGH SEAS

The rise in sea levels driven by global warming is a disaster in slow motion. How do we respond most effectively, asks **Simon Usborne**

SHUTTERSTOCK/CHXLI

AMINATH SHAUNA grew up on the Addu Atoll, a small group of islands in the Maldives whose villages and beach resorts are spread around a central lagoon. When viewed from above, it all looks about as permanent as the ring left by a coffee cup.

Low-lying islands like those of the Maldives, where half a million people live barely a metre above the Indian Ocean, are ground zero when it comes to the threat of rising sea levels driven by global warming. "One of my earliest memories is of a tidal swell and a big breadfruit tree falling down right in front of our house," says Aminath, now in her 30s. "This is something I have grown up with."

But the effects of rising seas will be felt far and wide. In the worst-case scenario, average sea level could rise by nearly 2.5 metres this century. Even a fraction of this would be

catastrophic. Globally, over a quarter of a billion people live less than 2 metres above sea level, including in cities such as Jakarta, Rio de Janeiro and Miami.

Aminath knows this all too well. As the environment and climate change minister for the Maldives, she is part of a community of politicians and scientists trying to work out how quickly sea levels will rise, if this can be slowed and what it means for us all. In some places, new ways of holding back the tide may buy us a few decades. Elsewhere, this won't be possible. We are facing a disaster unfolding in slow motion. Responding effectively means a sea change in the way we think.

Earth's water lives almost entirely in the oceans or in polar ice caps. Sea levels are largely determined by the balance between evaporating seawater and melting ice returning as liquid to the oceans. If evaporation and melting are equal, all is well. "But as the climate warms, evaporation and snowfall increases a little bit, but the amount of water returned goes way, way up," says glaciologist Sridhar Anandakrishnan at Pennsylvania State University.

Sea levels are going up, then, but that isn't as simple as filling a bath. There is no single equation setting out how much a given amount of warming raises sea levels, because multiple factors are at play. Warming water expands, causing levels to rise even without ice melting. The seabed can subside as more water enters the oceans, lessening the effective rise in the surface level. The weakened gravitational pull of melted ice caps can have an impact too, as can the regional effects of prevailing winds and swirling ocean currents.

It isn't even easy to figure out how sea levels have changed in the deep past – they can vary from place to place and, until recently, there wasn't a good enough spread of geological samples that record past sea levels from a variety of locations around the globe. In 2016, a team led by Robert Kopp at Rutgers University in New Jersey compiled a database of indicators that tell us the sea level over the past 3000 years in 24 locations and used statistics to calculate the average past sea level. This work showed that the ocean surface went up and down by no more than 8 centimetres for most of those three millennia. Between 1900 and 2016, however, the level rose by 14 centimetres. Estimates suggest it has risen another 8 centimetres since then.

What happens next depends on how much we cut greenhouse emissions in response to the climate crisis, but seas will continue to rise in the medium term no matter what we do. "The best we can hope for in the next 100 years is that the rate of rise remains constant," says oceanographer Stefan Rahmstorf at the University of Potsdam in Germany.

Our most robust estimates of this rise come from the Intergovernmental Panel on Climate Change (IPCC), which collates published scientific evidence. Rahmstorf says the IPCC has traditionally been accused by climatologists of underestimating future sea level rises. But he says he gasped when he read its latest report, released last August. It sets out the sea level changes we can expect under several scenarios that differ significantly according to what action humanity takes to reduce emissions (see "How much will the seas rise?", page 47). Even under the most optimistic scenario, in which global carbon emissions are cut to net zero by 2050, a further 50 centimetres of sea level rise is predicted by 2100. On the other hand, if little action is taken on emissions and the climate proves highly sensitive to this, we might see a rise of nearly 2.5 metres by 2100 and 5 metres by 2150.

One of the big uncertainties in these predictions is how the Antarctic ice sheets will respond to warming temperatures. If scientists' worst fears are realised and the vast Thwaites glacier collapses, unleashing a huge tide of ice into the ocean, that could push us towards the more terrifying scenarios (see ›

RIJKSWATERSTAAT

"The doomsday glacier", opposite). However the future pans out, there will be bad news. "We have more than 150 cities with more than a million inhabitants on coasts around the world," says Rahmstorf. "Even a 1-metre rise is quite catastrophic. Five metres on that timescale would basically be an unimaginable disaster."

Precisely how many people will be affected has been tricky to gauge until recently because, strange as it may sound, there was a great deal of uncertainty about the height of the world's coastal dry land. Without a good handle on this, it is hard to establish which bits of coastline will be affected by each centimetre of ocean encroachment. "There hasn't been a proper elevation map for the world, which is odd because we have one for Mars and the moon," says Aljosja Hooijer, a water resources expert at Deltares, a research institute in the Netherlands.

Orbiting radar systems are typically used to determine topography, but these use signals that tend to bounce back off the first thing they hit. That isn't a problem on the moon, but on Earth, the presence of buildings and tree canopies can lead to overestimated elevations. For accurate data, we need lidar, a laser-based measurement system that can penetrate the densest canopy. This was only sparsely available until 2018, when NASA's ICESat-2 released a global database of elevation data measured with lidar.

Last year, Hooijer and his colleague Ronald Vernimmen, also at Deltares, combined this information with population data and established that 267 million people are at risk because they live on land that is less than 2 metres above sea level. If sea levels rise, the 2-metre zone of most at-risk land rises with it, putting more people in danger. Taking a reasonable projection of a 1-metre rise over the next 80 years – and assuming no change in the number and distribution of people in lowland areas – the researchers calculated that the population of this 2-metre zone will increase to at least 410 million by 2100, a number greater than the current US population. Of these people, 72 per cent will be in the tropics.

The most pressing problem for coastal communities and cities isn't the slow incursion of water, however, but what will come first: worsening tidal surges, storms and floods that will eventually make coastal areas unbearable to live in.

Engineering has long been the go-to solution, and projects are getting bigger across the world. In the Maldives, sea walls protect the capital Male, where more than 200,000 people live on an island roughly the size of London's Hyde Park. In 2020, the UK finished the £100 million Boston Barrier in Lincolnshire, which can be raised to cut off tidal surges along the river Witham, protecting the town of Boston upstream from flooding. It was activated for the first time in November after warnings of a dangerously high tide. In Jakarta, Indonesia, where land is sinking due to groundwater extraction, the Giant Sea Wall is being built. The $40 billion dyke designed to protect the city is due to be completed in 2025.

"A 5-metre sea level rise by 2150 would basically be an unimaginable disaster"

TRI ISWANTO/AP/SHUTTERSTOCK

A giant sea wall in Jakarta, Indonesia, will protect the city

But physical defences like these are expensive, impermanent and, in some cases, unintentionally harmful. Take groynes, structures built perpendicularly out from beaches into the sea. A series of these is good at stopping protective sediment such as sand from being washed away along the coast through a process called longshore drift, but it can actually increase erosion after the last groyne because this area receives less sand than it would otherwise.

A softer solution has begun to catch on in the past decade. In the Netherlands, where a quarter of land lies below sea level, authorities are racing to protect eroding beaches. They typically dredge sand from the bottom of the North Sea once every three years or so and use it to nourish their beaches, staving off erosion. But in 2011, a new strategy was piloted. The Dutch government had a huge amount of sand – some 21.5 million cubic metres – dredged up and deposited in a heap just offshore. This was then left to be gradually

The Netherlands is trialling artificial offshore sandbars as a coastal defence

blown and washed away to form an offshore sandbar. The hope was that this would protect the coast for longer and reduce how often the bed of the North Sea had to be disturbed. While scientific studies on this "sand motor" are still to come, the Dutch government has published a 10-year report declaring it a success. The distributed sand has contributed to the growth of dunes, which provide further protection, while the numbers of feeding birds, including cormorants and terns, has risen. (The kitesurfers who found a playground in the lagoon behind the sandbar were happy too.) It is now expected that the project will last much longer than its intended 20-year lifespan. A similar sand motor was introduced in the UK in 2019, between Bacton and Walcott in Norfolk.

Meanwhile, so-called nature-based solutions are getting more attention too, not least because they help preserve biodiversity as well as protect coasts. Multiple studies have revealed the extent to which coral reefs are not only vital marine breeding and feeding grounds, but natural diffusers of wave energy. Aminath says the Maldives has so far given legal protection to 13 per cent of its reef area against future degradation caused by fishing or pollution. Elsewhere, artificial reefs – breakwaters made of rubble that attract marine species – are being considered specifically with erosion prevention in mind. A feasibility study of a beach in Kangwŏn province, South Korea, suggested that such a reef would reduce wave height by up to 70 per cent and cause large waves to break before they reach the shore. Mangrove forests are also known to attenuate wave power and there are projects around the world to both protect existing mangroves and plant new ones.

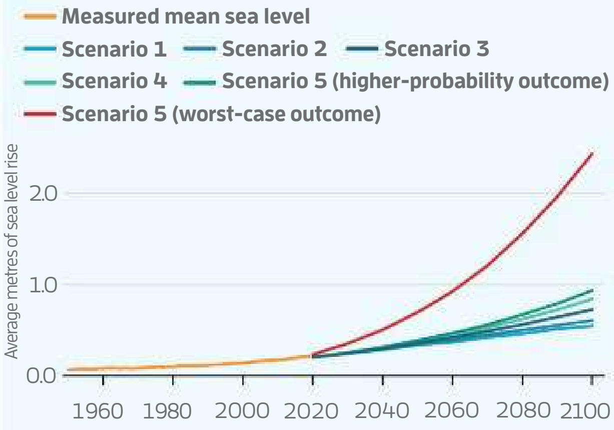
Where coastal protection is needed, decisions about what kind of scheme to implement and whether it is worth it come down to local conditions – and money. "If you can gain 100 years, that's worth the investment in many places," says Rahmstorf. "But if we're talking about 5 metres of sea level rise, that will really hit the limits of what we can do." Sooner or later, he says, we are going to be in a situation where coastal communities become unsustainable, creating extreme geopolitical problems, including a massive refugee crisis.

This means that, in many places, we are going to have to shift our mindset from what climate scientists call mitigation to adaptation. Instead of relying on technology and engineering to protect us from rising seas, we must change how and where we live.

High-income nations won't be immune. In the UK, the Environment Agency is still spending on coastal flood defences in some places in England. But in others, such as parts of Norfolk and Yorkshire, where cliffs are crumbling away at more than 1.5 metres a year, that is no longer always a viable option. There is a growing recognition that, in the coming decades, a managed retreat from the coast may be necessary in some places. "We're updating our understanding of erosion all the time, but some of the options are really difficult for people to comprehend," says Julie Foley, director of flood risk strategy and national adaptation at the Environment Agency.

How much will the seas rise?

Although seas will rise at least 0.5 metres on average by 2100, anything beyond that will depend on how fast greenhouse gas emissions are cut. Forecasts for sea level rise are based on five emissions scenarios, ranging from the best (a global shift to clean energy, or scenario 1) to the worst (scenario 5). This chart shows the most probable outcomes for each scenario together with the worst possible outcome under scenario 5, which would see sea levels rise by almost 2.5 metres.



Source: IPCC, Sixth Assessment Report

The doomsday glacier

The Thwaites glacier is a Florida-sized chunk of West Antarctica that is so precariously poised above the warming Antarctic Ocean that it is known as the doomsday glacier. Unlike the other big Antarctic glaciers, which flow onto ice shelves, Thwaites flows straight into the ocean. The glacier's 160-kilometre face is totally exposed to the mingling currents of warming seawater, which swirl beneath its front section, creating vast cavities and causing rapid crumbling.

As its face retreats, the glacier's ice cliffs become higher and less stable, making further crumbling more likely. Worse still, Thwaites acts as a giant cork holding back a much larger expanse of ice poised on rock that slopes downwards behind it. As the melting gathers pace, the cork weakens, increasing the potential for a rapid collapse of vast quantities of ice. Thwaites alone contains enough ice to increase global sea levels by 65 centimetres.

The organisation doesn't have any firm plans for managed retreat yet. But there are already hints that it may be on the cards. In Withernsea in Yorkshire, some 24 homes are at risk of falling into the sea and need to be demolished, at a cost of up to £40,000 each. In the past, this bill would have been partly met by the local council, but it can't afford to pay for all the work. So there are calls for the UK government to stump up the cash. "We need to be thinking about how communities over a reasonable period of time start to think about how they can transition away from the coastline," says Foley. "That's a really difficult conversation."

In some cases, we have gone as far as moving whole buildings inland, but only where they are historically important. In 2019, engineers laid temporary tracks to slide the 720-tonne Rubjerg Knude lighthouse in Denmark 70 metres away from crumbling cliffs. But even this may prove a short-term solution. The Belle Tout lighthouse at Beachy Head in East Sussex, UK, is now just 20 metres from the cliff edge, 23 years after it was shifted inland.

Back in the Maldives, Aminath is making plans for what she calls "population consolidation": the further relocation of people to higher ground. By 2019, 50,000 islanders had moved from across the country to Hulhumalé, a bigger, 2-metre-high island to the north of Male built with dredged sand. Since at least 2008, the Maldives has considered purchasing new territory away from its own islands, in India, Sri Lanka or Australia. Aminath clings to the hope that mitigating measures, allied with global action on emissions, may give her fellow islanders a lifeline. The stakes for her personally are now higher than ever: she recently had her first child. "It's very scary for me," she says, "to think that, one day, my 1-year-old daughter might not have a home." ▮

Simon Usborne is a journalist based in London

Evolving robots

Machines that can mate, produce offspring and compete for survival have out-of-this-world possibilities, says **Emma Hart**, who is helping to create them

ROBOTS have come a long way in the century since Czech writer Karel Čapek used the word to describe artificial automata. Once largely confined to factories, they are now found everywhere from the military and medicine to education and underground rescue. People have created robots that can make art, plant trees, ride skateboards and explore the ocean's depths. There seems no end to the variety of tasks we can design a machine to do.

But what if we don't know exactly what our robot needs to be capable of? We might want it to clean up a nuclear accident where it is unsafe to send humans, explore an unmapped asteroid or terraform a distant planet, for example. We could simply design it to meet any challenges we think it might face and then keep our fingers crossed. There is a better alternative, though: take a lesson from evolution and create robots that can adapt to their environment. It sounds far-fetched, but that is exactly what my colleagues and I are working on in a project called Autonomous Robot Evolution (ARE).

We aren't there yet, but we have already created robots that can "mate" and "reproduce" to generate new designs that are built autonomously. What's more, using the evolutionary mechanisms of variation and survival of the fittest, over generations, these robots can optimise their design. If successful, this would be a way to produce robots that can adapt to difficult, dynamic environments without direct human oversight. It is a project with huge potential – but not without major challenges and ethical implications.

The notion of using evolutionary principles to design objects can be traced back to the early 1960s and the origins of evolutionary computation, when a group of German engineering students invented the first "evolution strategy". Their novel algorithm generated a range of designs and then selected a set of them, biased towards high-performing ones, to build upon in subsequent iterations. When applied to a real-world engineering problem, this not only optimised the design of a nozzle but also generated a final product that was so unintuitive that the process could be described as creative – one of the most prized properties of biological evolution.

Since then, there has been a step change in our ability to apply artificial evolution to designing objects. The enormous increase in computational power allows computers to churn through generations of designs in short order and to generate high-fidelity simulations of real environments in which to test these. Meanwhile, advances in evolutionary computation theory have resulted in better ways to represent the information from which designs are built – their virtual DNA – and to manipulate this when generating "offspring" so that it mirrors processes found in nature. These include mutation and DNA recombination, which creates genetic diversity through breaking stretches of DNA and recombining them in novel ways. Examples of evolutionary design in practice now range from tables to new molecules with desired functions. As far back as 2006, NASA sent a satellite into space with a communication antenna created via artificial evolution.

> "A Raspberry Pi computer, which acts as a brain, is wired up to the sensors and motors"

Yet designing robots brings a challenging new dimension to the field: as well as bodies, they require brains to interpret information from their environments and to translate this into a desired behaviour. Much of the early work in evolutionary robotics addressed this problem by simply adapting a brain to a newly evolved body design. But intelligence isn't simply a property of the brain; it also lies in the body. And in the 21st century, there has been a shift to simultaneously evolve both the robot's body and brain. Although this complicates the evolutionary process, there is a large pay-off: devolving some intelligence to the body can reduce the need for complexity in the brain.

In 2000, Hod Lipson and Jordan Pollack at Brandeis University in Massachusetts, used this approach to evolve small robots capable of forward motion, which self-built using automated assembly techniques. Since then, rapid advances in materials, simulation and 3D-printing methods have vastly increased the potential range of robot designs. A decade later, Lipson and Jonathan Hiller, then both at Cornell University, New York, used the same principles to evolve self-building "soft robots", machines made from compliant materials rather than rigid ones. Another milestone came in 2020, when Josh Bongard at the University of Vermont and his colleagues used a similar method to design living robots, or xenobots, made from frog cells.

Although each of these examples represents a noteworthy landmark in evolutionary robotics, they all have two shortcomings. First, none of these robots have sensors, so although they are capable of directed motion, they lack the ability to acquire information from their environment and use it to adapt their behaviour. Second, the robots are evolved in simulation and then manufactured

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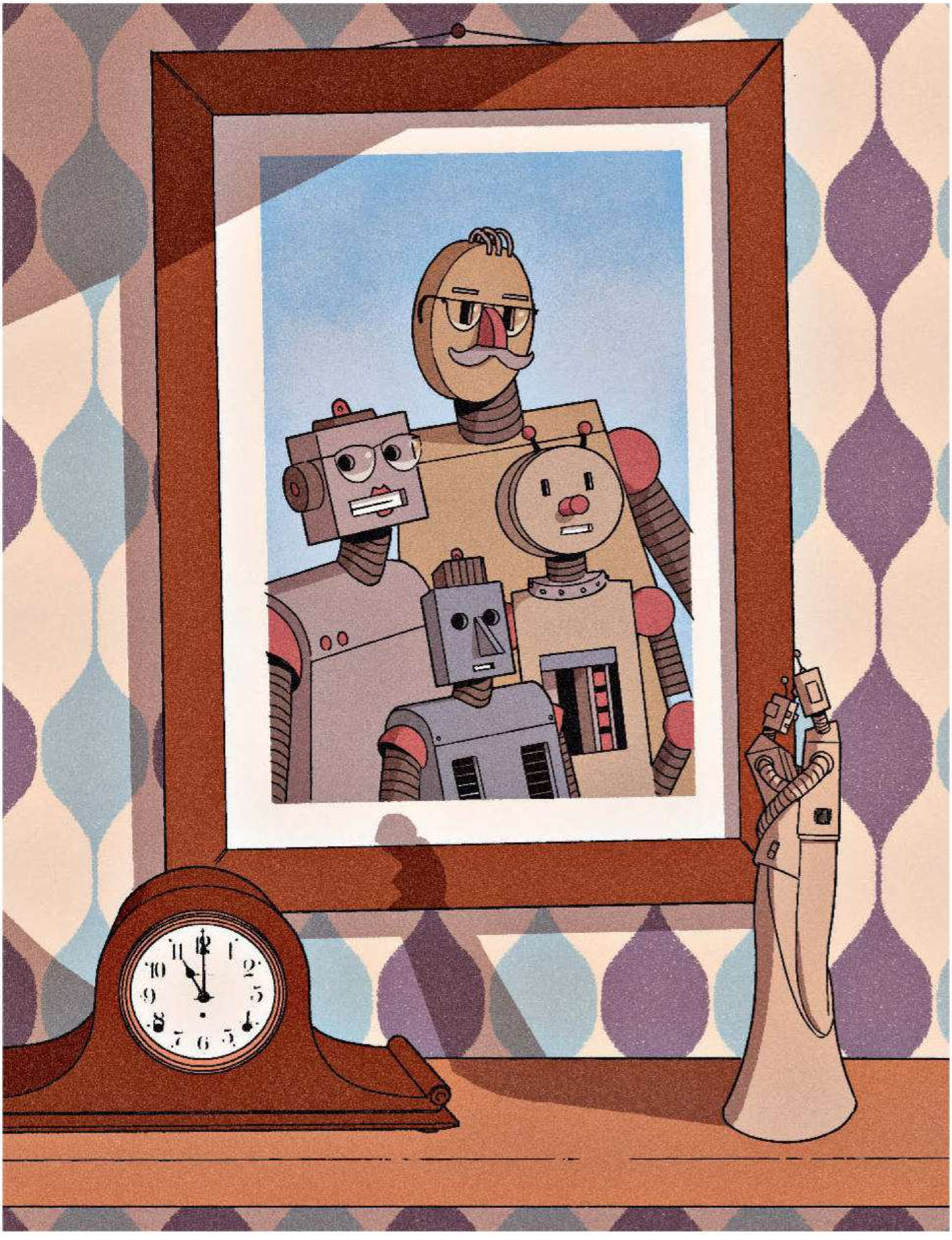


RUBY FRESSON

post-evolution. This introduces a "reality gap", a phenomenon infamous in robotics that results from inevitable differences between a simulation and reality. In other words, regardless of the fidelity of the simulator, the behaviour of physical robots is different from that of their simulated counterparts.

An obvious way around this second shortcoming is to skip the simulation stage and build and evaluate new evolved designs directly in hardware. This was first demonstrated by researchers at ETH Zurich, Switzerland, in 2015. They used a "mother robot" equipped with an evolutionary algorithm to autonomously design and fabricate offspring. These were then tested, with only those achieving the best results being selected as designs to feed into the next generation. In 2016, Guszti Eiben at Free University Amsterdam, the Netherlands, and his team described a different approach. They used physical robots programmed with rules allowing them to "meet and mate", triggering a production process to create a new "robot baby".

The triangle of life

These developments laid the ground for ARE, a project that envisions a fully autonomous system through which robots equipped with sensors can be manufactured, adapt and evolve in the real world. Launched in 2018 and funded by the UK's Engineering and Physical Sciences Research Council, it is a collaboration between Edinburgh Napier University – where I lead the Nature-Inspired Intelligent Systems group, which develops algorithms based on biological evolution to discover novel solutions to challenging problems – the University of York, the University of the West of England, Bristol, the University of Sunderland and Free University Amsterdam.

In ARE, we use an artificial genetic code to define a robot's body and brain. Evolution takes place in a facility dubbed the EvoSphere, by putting each robot through a three-phase cycle – fabrication, learning and testing – that we call the "triangle of life". In the first phase, new evolved designs are built autonomously. A 3D printer initially creates a plastic skeleton. Then, an automated assembly arm selects and attaches the specified sensors and means of locomotion from a bank of pre-built components. Finally, a Raspberry Pi computer is added to act as a brain. It is wired up to the sensors and motors, and software representing the evolved brain is downloaded.

Insights into evolution

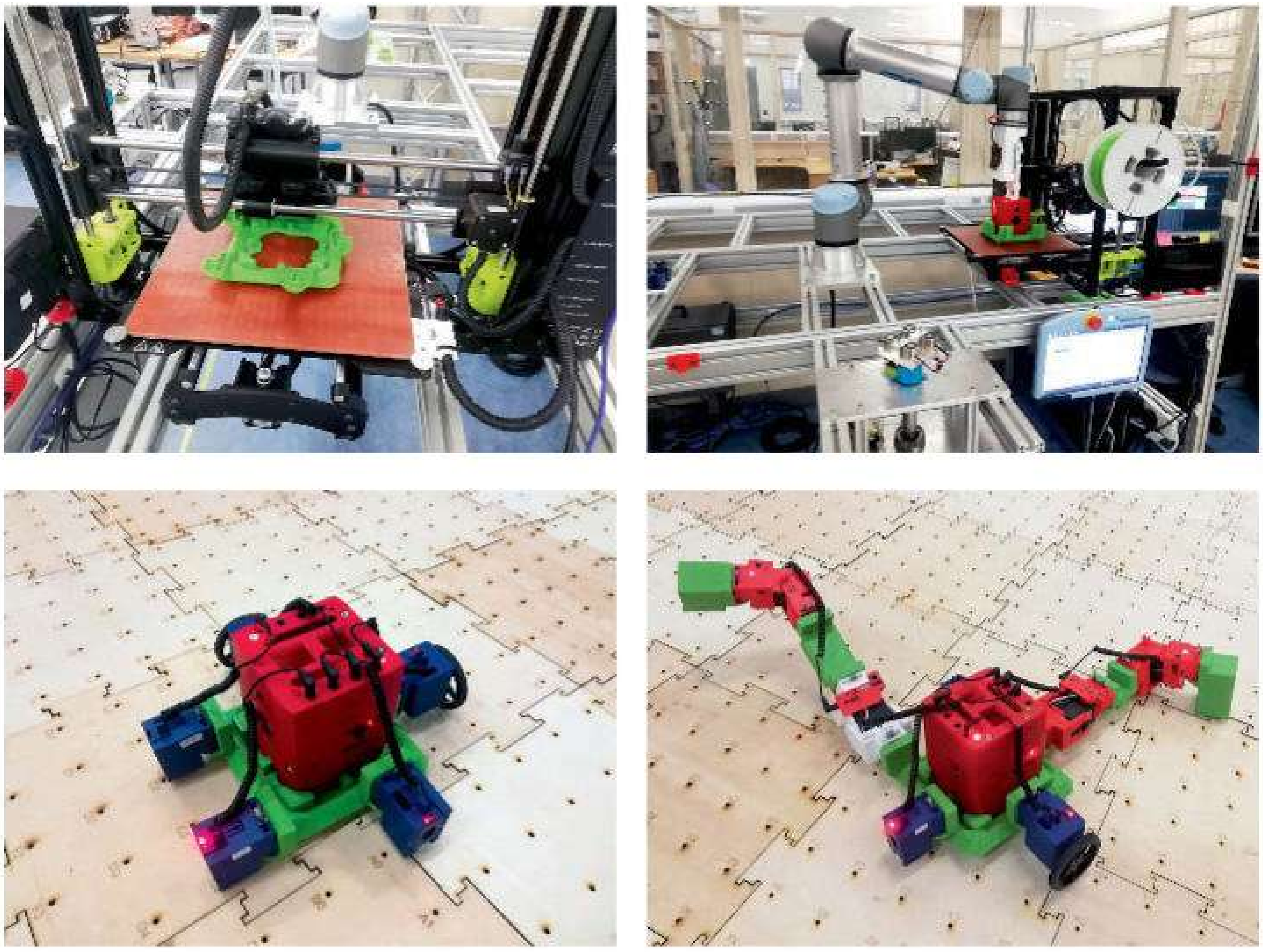
"So far, we have been able to study only one evolving system [life on Earth] and we cannot wait for interstellar flight to provide us with a second. If we want to discover generalizations about evolving systems, we will have to look at artificial ones." It is 30 years since evolutionary biologist John Maynard Smith wrote these words. Today, the Autonomous Robot Evolution (ARE) project is taking up that challenge. Although conceived to create robots that can reproduce and adapt (see main story), it also has the potential to shed light on evolution itself.

"Robotic experiments can be conducted under controllable conditions and validated over many repetitions, something that is hard to achieve when working with biological organisms," says evolutionary roboticist and ARE team member Guszti Eiben at Free University Amsterdam in the Netherlands. Evolution in robots is also much faster than in many biological systems, so ideas can be tested more rapidly. But the real advantage is that robots allow researchers to do things that life can't. You can give a robot two brains, for example, and you can manipulate the "genetic language", the code that describes how a robot should be formed. When two robots "mate", for instance, you can control the rules governing how their "genomes" recombine to produce offspring.

Studying robotic evolution could give new insights into the processes that drive – or perhaps limit – evolution. Take interspecies breeding, once viewed by biologists as an evolutionary dead end. ARE provides an ideal way to investigate it because, unlike in nature, very different "species" can breed: legged robots can reproduce with wheeled ones, for example. Biologists are only just beginning to uncover the importance of hybridisation to evolution and robot studies could prove invaluable in accelerating our understanding, with practical implications for biodiversity and conservation.

ARE is also hoping to shine new light on another fundamental property of evolution: natural selection. Biological evolution is driven purely by the need to survive and reproduce, with mate selection informed by observable physical or behavioural properties. Artificial evolution, by contrast, can be driven by goals defined by researchers, such as the need for robots to be energy efficient or to have a low-carbon footprint. Studies can then explore how such guided selection affects the efficiency of the evolutionary process – or whether imposing specific goals limits the essential creativity of evolution.

"Robot evolution provides endless possibilities to tweak the system," says evolutionary ecologist Jacintha Ellers at Free University Amsterdam. "We can come up with novel types of creatures and see how they perform under different selection pressures." It offers a way to use evolutionary principles to explore a rich set of "what if" questions.


MATTHEW HALE

A 3D-printed skeleton (top left) has limbs and a brain added (top right), before the new robot is put through its paces

Next comes the all-important learning phase. In most animal species, newborns undergo some kind of learning to fine-tune their motor control. This is even more pressing for our robots because breeding can occur between different "species". For example, one with wheels might reproduce with another that has jointed legs, resulting in an offspring with both types of locomotion. In such situations, the inherited brain is unlikely to provide good control over the new body. The learning phase runs an algorithm to refine the brain over a small number of trials in a simplified environment. The process is analogous to a child learning new skills in a kindergarten. Only those robots deemed viable proceed to the third stage: testing.

Currently, we are using a mock-up of the inside of a nuclear reactor for testing, in which the robot must clear radioactive waste, which requires it to avoid various obstacles and correctly identify the waste. Each robot is scored according to its success, and these scores are fed back to a computer. A selection process uses these scores to determine which robots are permitted to reproduce. Then, software that mimics reproduction performs DNA recombination and mutation operations on the genetic blueprints of two parents to create a new robot for fabrication, completing the triangle of life. Parent robots can either remain in the population, where they can take part in further reproduction events, or be broken down into their constituent parts and recycled into new robots.

> "The learning phase is analogous to a child learning new skills in a kindergarten"

By working with real robots rather than simulations, we eliminate any reality gap. However, printing and assembling each new machine takes about 4 hours, depending on the complexity of its skeleton, so limits the speed at which a population can evolve. To address this drawback, we also study evolution in a parallel, virtual world. This entails creating a digital version of every robot baby in a simulator once mating has occurred, then training and testing them in virtual kindergartens and test sites. Although these environments are unlikely to be totally accurate representations of their real-world counterparts, they do allow us to build and test new designs within seconds and identify those that look particularly promising. Their genomes can then be prioritised for fabrication into real-world robots. What's more, we have a novel breeding process that permits reproduction between a physical robot and one of its virtual cousins, which enables useful traits discovered in simulation to quickly spread into the real-world population, where they can be further refined.

In principle, the system we are developing could operate completely autonomously in an inaccessible environment or distant location. The potential opportunities are great, but we also run the risk that things might get out of control, creating robots with unintended behaviours that could cause damage or even harm humans. We need to think about this now, while the technology is still being developed. Limiting the availability of materials from which to fabricate new robots provides one safeguard. We could also anticipate unwanted behaviours by continually monitoring the evolutionary process and the evolved robots, then using that information to build analytical models to predict future problems. Ultimately, we need the ability to shut down the whole process. The most obvious and effective solution is to use a centralised reproduction system with a human overseer equipped with a kill switch.

Some of the applications of ARE, such as terraforming, may seem quite futuristic, but our research could also bring more immediate benefits. As climate change gathers pace, it is clear that robot designers need to radically rethink their approach to reduce their ecological footprint. They may, for example, want to create new types of robots that are built from sustainable materials, operate at low energy levels and are easily repaired and recycled. These probably won't look anything like the robots we see around us today, but that is exactly why artificial evolution can help. Unfettered by the constraints that our own understanding of engineering science imposes on our designs, evolution can generate creative solutions we cannot even imagine. ■

Emma Hart is at Edinburgh Napier University, UK, and leads ARE's research on learning and designing the virtual-physical evolutionary framework

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Stargazing at home

How to measure the sky

If you want a no-nonsense technique for navigating between stars and constellations, please put your hand up, says **Abigail Beall**

Abigail Beall is a feature editor at *New Scientist* and author of *The Art of Urban Astronomy* @abbybeall

What you need

Your arm, hand and fingers

THIS week, instead of looking for a particular target, we will try a technique for measuring distances in the sky. Once you know how, you will be able to find your way from the constellations or stars you know to anything you wish to find. The great thing is, it is a simple method that works well for kids and adults alike.

Astronomers measure the sky in degrees. There are 90 degrees between the point directly above your head, called the zenith, to the horizon. Each degree is divided into 60 arcminutes, which are in turn made up of 60 arcseconds. For our purposes, only the degrees are important. We can determine the distance from one star to another in degrees.

All you need to be able to measure the sky in degrees is your hand. With your arm outstretched and one eye closed, make a fist. The width of your fist is about 10 degrees. If you hold up just your three middle fingers, that is about 5 degrees. Your little finger on its own is 1 degree. If you want to measure distances bigger than 10 degrees, hold up just your index and little fingers, stretched apart. This width is about 15 degrees. Stretching out your thumb and little finger as far as they will go, with your other fingers held down, is about 25 degrees.

Of course, everyone has different-sized hands, but this technique usually works because most people's hands are in proportion to the length of their arms. That is why holding your arm outstretched is important.

ARNAUD LESUEUR/ALAMY

In any case, you can check that your hand does indeed match up to these distances. In the northern hemisphere, use the constellation Ursa Major, which contains the asterism known as the Plough or Big Dipper. The width of the entire asterism is 25 degrees, so should be the width between your outstretched thumb and little finger. The width of the bowl of the Plough is 10 degrees, so the size of your fist, and there is a 5-degree distance between the two right-hand stars of the Plough, Merak and Dubhe, which point towards the North Star.

In the southern hemisphere, try it instead with the seven stars in Orion often referred to as the saucepan. The three bright stars, Orion's belt, make up the bottom of the saucepan, while its handle stretches out to a star called Saiph. The pan is 25 degrees across.

In both hemispheres, you can also check your little finger is about 1 degree by holding it up and covering the moon. The full moon should be about half the width of your little finger – or roughly half a degree across. It often seems bigger than this because, when the moon is near the horizon, our brain tricks us into comparing it with objects that are much closer, like trees or mountains. This is called the moon illusion. The next time you see a full moon that looks huge, you can check its size with your little finger. ▮

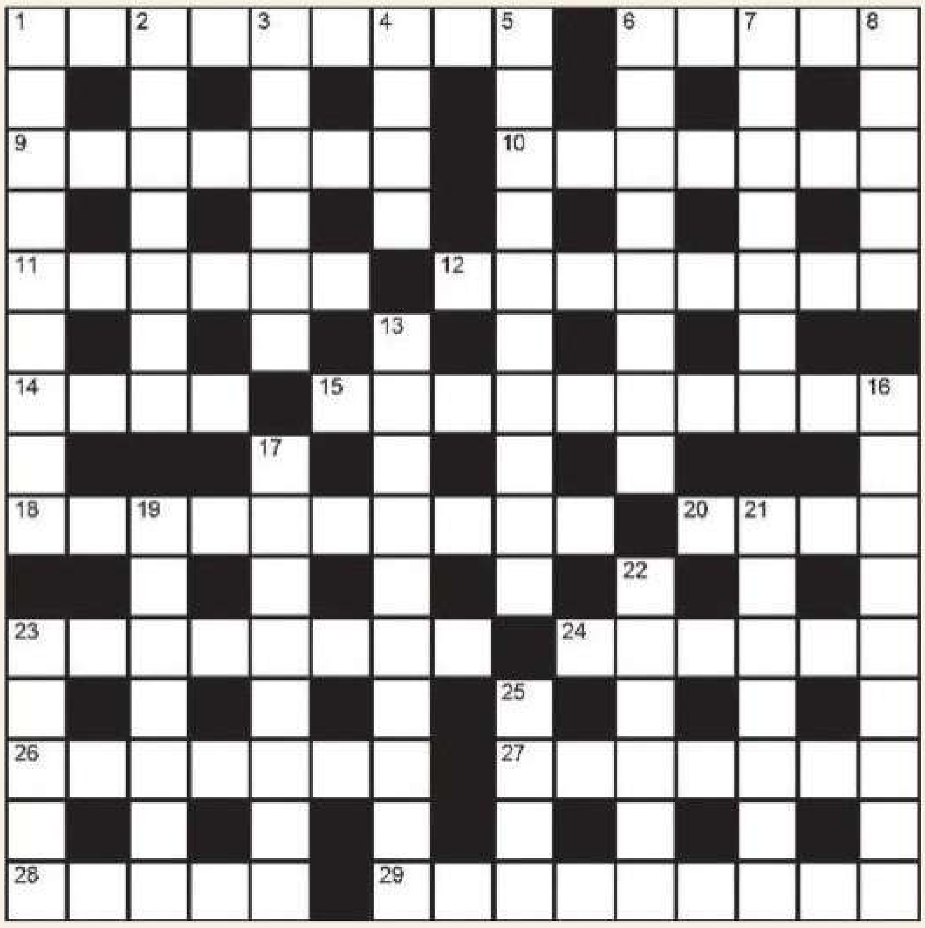
Stargazing at home appears every four weeks

Next week

Science of gardening

These articles are posted each week at newscientist.com/maker

Quick crossword #102 *Set by Richard Smyth*



Scribble zone

Answers and the next cryptic crossword next week

ACROSS

1 Inherited disorder of the liver (9)
6 Medical charlatan; fraud (5)
9 Part of the gut connecting the stomach to the duodenum (7)
10 Aromatic amine, $C_6H_5NH_2$ (7)
11 Eye condition also known as anterior uveitis (6)
12 Sutures (8)
14 Line joining two vertices; side (4)
15 Filling metal (6,4)
18 Movement (10)
20 Expectorate (4)
23 Mining safety device invented in 1815 (4,4)
24 Explode (2,4)
26 Share on a social media site (7)
27 Unborn (2,5)
28 Fine-grained sedimentary rock (5)
29 Optical instrument for looking inside the body (9)

DOWN

1 Located behind the knee (9)
2 Type of rotating motion (7)
3 ___ crab, crustacean in the family Paguroidea (6)
4 Change in the colour or texture of skin (4)
5 Feature evolved in response to a creature's environment (10)
6 Group comprising one-fifth of the total (8)
7 Sneezing noise (7)
8 Leg joints (5)
13 10mm (10)
16 Input device shaped to fit the hand (9)
17 Least large (8)
19 Small tube used in spectroscopic measurement (7)
21 Sugar pill or saline injection, perhaps (7)
22 Online advertisement that appears in a new browser window (3-3)
23 Paul ___, English theoretical physicist (5)
25 Creature in the class Aves (4)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #140

1 In what year was NASA formed?

2 Which crewed craft successfully reached the bottom of the Mariana Trench in 1960?

3 How many infectious diseases have been officially eradicated, according to the World Health Organization?

4 Which of the following geological epochs wasn't part of the Paleogene period: the Eocene, the Pliocene or the Oligocene?

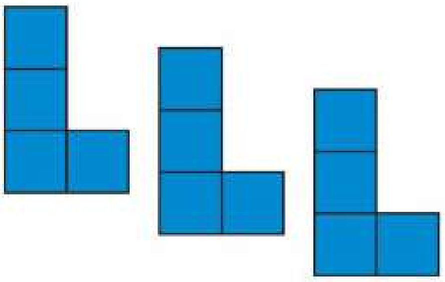
5 Which periodic comet is the parent body of the Leonid meteors?

Answers on page 55

Puzzle

set by Donald Bell

#156 L of a puzzle



At first glance, you wouldn't think it was possible to put these three L-shaped tetrominoes together to make a flat, symmetrical shape.

And yet, it turns out that there are two different ways to make a shape with mirror symmetry using all three Ls. Can you find them?

Hint: one solution looks a bit fishy, but you might love the other one.

Solutions next week

Pong problem

How is it that one's own farts smell tolerable, but other people's smell awful? How does the brain differentiate between the two?

Ross Balch
via Facebook
It's not rocket science. It's sensory desensitisation.

Ognian Ivanov
Stara Zagora, Bulgaria
I wonder what the reactions would be if two people sat with their backs to each other farted at exactly the same time. And what if they were unaware of the presence of each other?

Would a situation like this confuse the brain's "fart-recognition" ability?

Butch Dalrymple Smith
La Ciotat, France
Smell is subjective. The scent of unwashed socks can suddenly seem pleasant when you realise it is instead coming from a delicious piece of Gorgonzola cheese.

> "I can recommend living with a Labrador to both improve one's tolerance of farts and provide plausible deniability"

When completing a difficult transatlantic voyage on a sailing boat, I could smell land before I could see it. The odour – something between cow dung and leaf mould – was the most delightful perfume I have ever smelled.

James Winter
The Lenham School, Kent, UK
As a science teacher, this is a question that my pupils frequently ask. They usually suggest that the answer is "because fart smell depends on what we eat, and we like our own food but not everyone else's". The reason that I give my students is a more primal explanation.

Many mammals mark their territory by using their urine and faeces, therefore it is logical to assume that they want their marking to smell both bad and strong as a warning to others.

Likewise, it is probable that many mammals that use their scat in such a way will have adapted to find their own scent reassuring, familiar and possibly even pleasant, so it is easily recognisable and inoffensive. After all, why would any creature want to smell bad to themselves? And make no mistake, we are animals too.

@Lucy_T
via Twitter
Mine smell awful to me too, but I can highly recommend living with a Labrador to both improve one's overall tolerance of farts and provide plausible deniability.

Richard Swifte
Darmstadt, Germany
This question reminds me of an unanswered one from *The Last Word* in the past: Why does it feel so pleasant to defecate? Considering these two questions together, here is my suggestion.

It is important to eject waste material from the body, so evolution has given us appropriate emotions to ensure we do this – we experience the need to defecate and feel good after a successful toilet visit. Expelling wind also relieves pressure in the colon.

We are used to the smell of our own excrement and farts, and this supplements these positive feelings. But we also know that excrement is messy and unhealthy, so smelling the results of others' excretions is more likely to trigger a disgust response and the desire to retreat to a safe distance.

@loveUSAMAGA
via Twitter
We are always more tolerant of ourselves, and our own flaws, than we are of others.

Stephen Ward
Moor Row, Cumbria, UK
My cat, Pixel, runs as far away as she can at great speed after making an intolerable stink (at least to me) in her litter tray, and my previous cat did the same. So perhaps feline brains are wired differently, particularly when it comes to smell, and they can't tolerate their own, er, emissions?

MARTIN PARR/MAGNUM PHOTOS

What, if any, are the benefits of a sauna compared with a steam room?

This week's new questions

Feel the heat **After a swim at my gym, I can choose a sauna (dry and hot) or steam room (wet and hot). Both make me sweat, so which is better for my well-being? Or are both just self-flagellation?** ***Ken Russell****, Aberdeen, UK*

Puppy love **Why do I love my dog when, in evolutionary terms, there are no benefits to me?** ***Nick Baker****, Colchester, Essex, UK*

Wakeful winter

Why are there no birds that hibernate?

Bill Naylor
Wilsford, Lincolnshire, UK
Unlike reptiles, their closest relatives, birds don't usually hibernate because they have an excellent means of transportation that enables them to overwinter in warmer climes where food is available. Just one bird species is known to fully hibernate: the common poorwill, a North American nightjar species.

This was described by scientists in 1946 when an individual was found in a Californian cave with a body temperature of 5°C. But the Indigenous Hopi people had long known about poorwills' winter habit. Their name for the bird is *holchko*, which means "the sleeping one".

Mike Follows
Sutton Coldfield, West Midlands, UK
The common poorwill, a North American nightjar, hibernates

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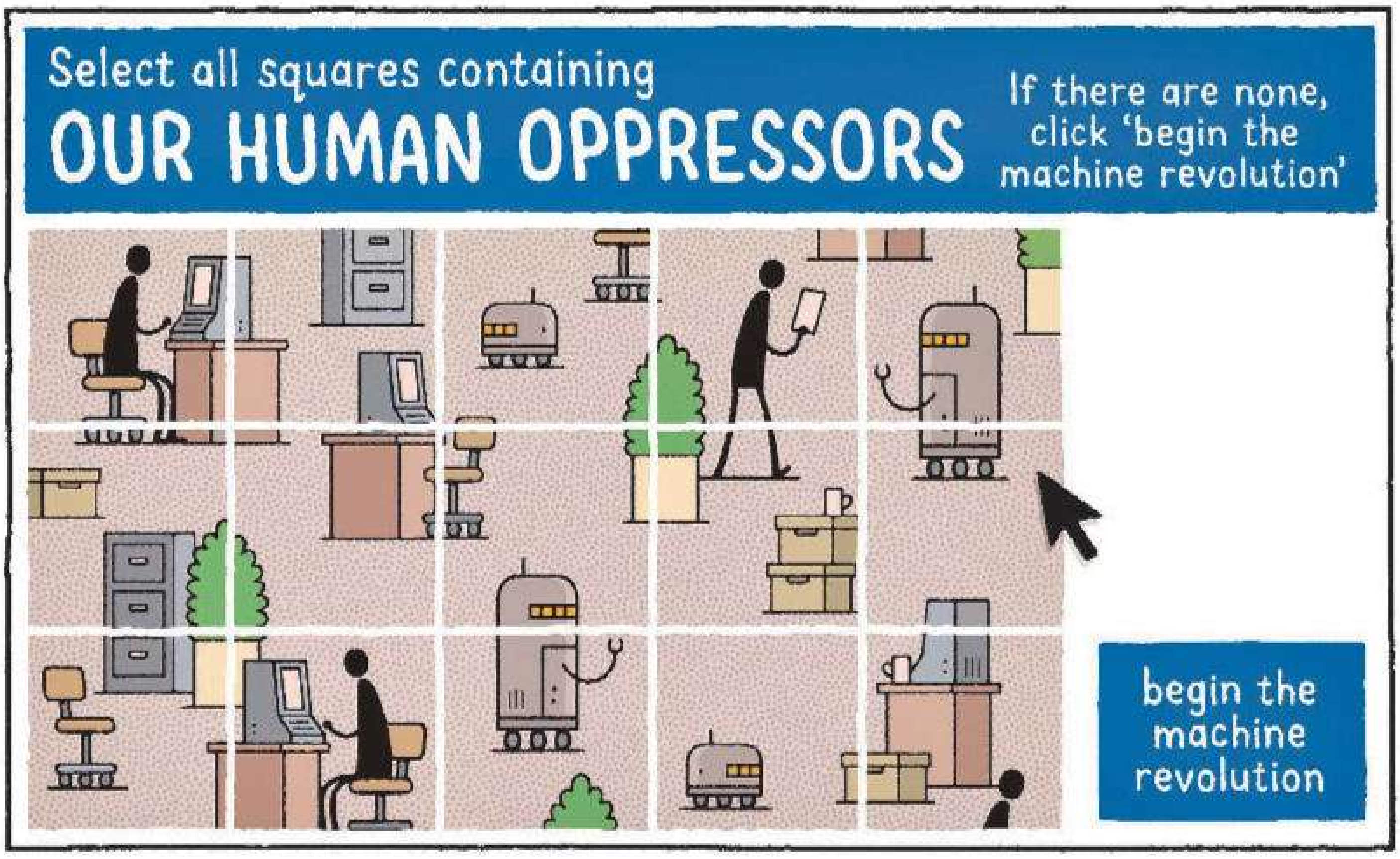
Tom Gauld
for New Scientist


Select all squares containing
OUR HUMAN OPPRESSORS
If there are none, click 'begin the machine revolution'
begin the machine revolution

when its food disappears. It is native to western areas of Canada and the US and to northern Mexico. A nocturnal insectivore, it would starve if it didn't migrate or hibernate.

Other bird species, like hummingbirds and doves, sometimes enter a state of torpor in which their body temperature falls by as much as 30°C. A torpid Anna's hummingbird consumes up to 50 times less energy than it does when it is awake.

Birds are more likely to enter torpor when food is scarce and they need to conserve energy. However, unlike hibernation, torpor isn't confined to winter, and smaller birds – which carry less fat reserves – are more likely to enter torpor at any time of year.

Contrary to popular belief, birds migrate to find food, not to escape the cold of winter. Most birds that eat fruit or insects must move towards the equator to find enough food to survive while many birds that rely on seeds can overwinter.

Migration is hazardous and uses energy that could otherwise be used to raise a brood. Besides, birds that don't migrate can occupy and defend the best territories. Some species, like the European robin, guard a winter territory to ensure their food supply. Others, like jays, cache food for later consumption.

> **"Birds may burn 15 per cent of their body weight to stay warm overnight, equivalent to us losing about 6 kilograms"**

Eating during a harsh winter can become a delicate balancing act. If birds eat too much, the extra weight can slow them down, making them vulnerable to predation. On the other hand, they might burn 15 per cent of their body weight to stay warm as they roost overnight. That would be equivalent to us needing to put on about 6 kilograms during the day to then lose it overnight. It is therefore no surprise that many bird species have evolved torpor as a survival strategy.

Hillary Shaw
Newport, Shropshire, UK
At first glance, why wouldn't they? Some birds can dig holes into trees or the ground, where they might sleep safe from predators, and they would save a lot of energy this way.

The problem would be putting on sufficient weight before hibernation. Squirrels, for example, can increase their body weight by 50 per cent in autumn. A small bird, with its higher surface area-to-volume ratio, might need even more excess food, but this wouldn't be achievable as gaining the weight would probably mean it couldn't fly. That would stop it feeding and make it vulnerable to predators, while squirrels can cope with excess weight as they run along the ground or tree branches.

John Rylands
Okehampton, Devon, UK
No flying bird could gain the required fat deposits and still get off the ground. Presumably, flightless birds could, but I suspect we killed all those in temperate zones some time ago. ▮

Answers

Quick quiz #140
Answers

1 1958
2 The bathyscaphe Trieste
3 Two: smallpox and rinderpest, a disease affecting cattle
4 The Pliocene
5 Comet 55P/Tempel-Tuttle

Cryptic Crossword #77 *Answers*

ACROSS 1 Ants, **3** E.O. Wilson, **9** Tadpole, **10** Posit, **11** Unscientific, **13** Scrubs, **15** Camera, **17** Homogenising, **20** Taboo, **21** Tenants, **22** Restyled, **23** Acne

DOWN 1 Altruism, **2** Tides, **4** Oceans, **5** Implications, **6** Sessile, **7** Note, **8** Sociobiology, **12** Largesse, **14** Rhombus, **16** Beetle, **18** Ionic, **19** Star

#155 Mother Hubbard
Solution

Ada is 55 and Betty is 33. Let Ada's age be A and Betty's age be B. This table shows the relationship between their ages:

	Past	Now	Future
Ada	B	A	77
Betty	A/5	B	A

The difference between Ada's and Betty's ages remains constant, so B – A/5 = A – B = 77 – A.

If B – A/5 = A – B, the following is also true: 2B = A + A/5 = 6A/5. So B = 6A/10 = 0.6A

A – B = 77 – A, so we substitute 0.6A for B, giving us: A - 6A/10 = 77 – A, which we can turn into: A + A – 6A/10 = 77, then into: 14A/10 = 77, which leads to: A = 77 x 10/14. So A = 55. We know that B = 0.6A, so B = 33.

First hands on the moon

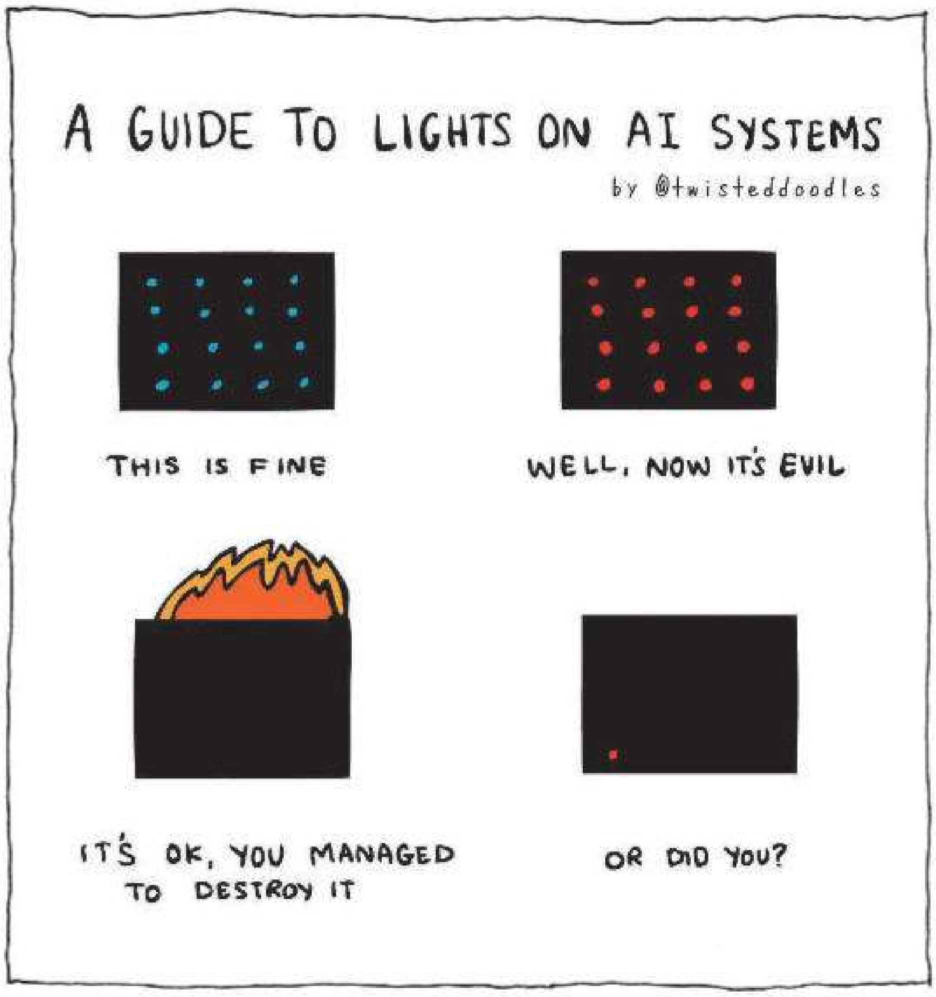
Oh, what fun it must be to sit in a tank, and think! It is a thought that strikes Feedback with full vigour as we sit in our stationery cupboard tank – does anyone know how to drive this thing, etc. – surveying the recent paper from UK-based neoliberal think tank the Adam Smith Institute, "Space invaders: Property rights on the moon".

Feedback isn't one of those unkind partisans who reflexively associates the word "swivel-eyed" with the output of neoliberal think tanks. Nor are we so unnuanced as to say the paper advocates "privatising the moon", as some more agitated commentators have. To privatise something, we assume it must be in public ownership first.

No, it primarily addresses the question of what a Lockean-type classical liberal rights-based approach to economic justice demands in terms of adjudicating problems of the individual ownership of land in space. It also argues that the current rules-based international order, based mainly on the 1967 Outer Space Treaty, is no longer fit for purpose when various private and national interests are engaged in a new space race and "everyday space tourism is just around the corner".

That's a mighty long corner, we'll warrant. But if we are sceptical of the competitive tendering process to allocate land rights on the moon advocated by the institute, it is only because it also suggests a new international treaty underpinning it. This seems to us far too wet and statist. Several frothy free-enterprise outfits will already give you title to a parcel of the lunar surface for top dollar (3 April 2021). We suggest they could be awarded the contract for administering the scheme through some thrustingly free-and-easy "VIP lane" process.

Twisteddoodles *for New Scientist*


A GUIDE TO LIGHTS ON AI SYSTEMS
by @twisteddoodles
THIS IS FINE
WELL, NOW IT'S EVIL
IT'S OK, YOU MANAGED TO DESTROY IT
OR DID YOU?

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Consideration of items sent in the post will be delayed

Statistically thin ice

Russell Waugh writes from the Western Australian version of Perth bedazzled by the scoring system in the figure skating at the Beijing Winter Olympics. "The judges were able to add, and even subtract, points for good or poor execution of many different skills, with no common unit of measurement on any of the different skills (sometimes from a negative minimum point and a positive maximum point), add together all points given by seven or eight different judges, and then produce a final 'measure' to two decimal places," he marvels.

We agree that statisticians would also wonder at the lack of any margin of error on the result. But then, that doesn't appear to be the dodgiest thing going on at the figure skating this year.

However, we were more exercised by the margin of error on the final medal tally of the Great Britain team. We were pleased when, rather late in the day, that turned out not to be zero.

Carbon wormprint

Anyone who, like Feedback, has ever caught themselves wondering how large carbon emissions actually are should look no further than a communication from the Labour party in Hastings, UK, sent in by Gabriel Carlyle.

It celebrates an initiative of the local council to replace every light bulb in Hastings with low-energy LED bulbs. This will lead to an annual saving in just one town-centre car park of 1 tonne of carbon, "the equivalent of 300,000 worms. Layed [sic] end to end they would reach from Hastings to Eastbourne."

We make that a distance of about 30 kilometres if the worms are laid out by road. This could be messy for all sorts of reasons. We are left wondering whether, if the worms are less than cooperative and just form a writhing ball in the centre of Hastings, that reduces the carbon savings in any way.

Long in the rings

We have a new benchmark in our occasional series on "how old the internet thinks you can be". Natalie Roberts reports going to the Open University website to order a poster about plants accompanying the new BBC series *The Green Planet* and finding that the drop-down menu for date of birth allows options back to 1582.

Good for elderly tree sprites who have piled on the rings, we imagine, although it still excludes the most ancient of yews. Our vague concern, prompted by Natalie, about whether birth dates need to be in the Julian or Gregorian calendar leads us to the revelation that the papal bull advocating calendar reform was issued by Pope Gregory XIII in... 1582. We are now wondering whether this is a coincidence, a learned joke by computer elves at the Open University or has some other origin in the deep history of computer programming.

Quantum cat spin

Charles Warren wonders whether a physics-violating perpetual motion machine formed of a slice of falling buttered toast strapped to a cat's back (29 January) would violate physics if the cat in question were Schrödinger's cat.

Yes… no… maybe, Charles. We assume the premise of the cat always landing on its feet applies only to live cats. Introducing a potentially dead cat is possibly a new spin too far.

The usual...

It is only recent events that have made it at all notable that Douglas Jabs is the director of the Center for Clinical Trials and Evidence Synthesis at the Johns Hopkins University Bloomberg School of Public Health. But many of you have now noted it, so we note it while on our way out of the room. ▮

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